AUGUST 1956

Journal

VOL. 48 • NO. 8

AMERICAN WATER WORKS ASSOCIATION

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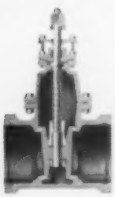

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Journal

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August 1956

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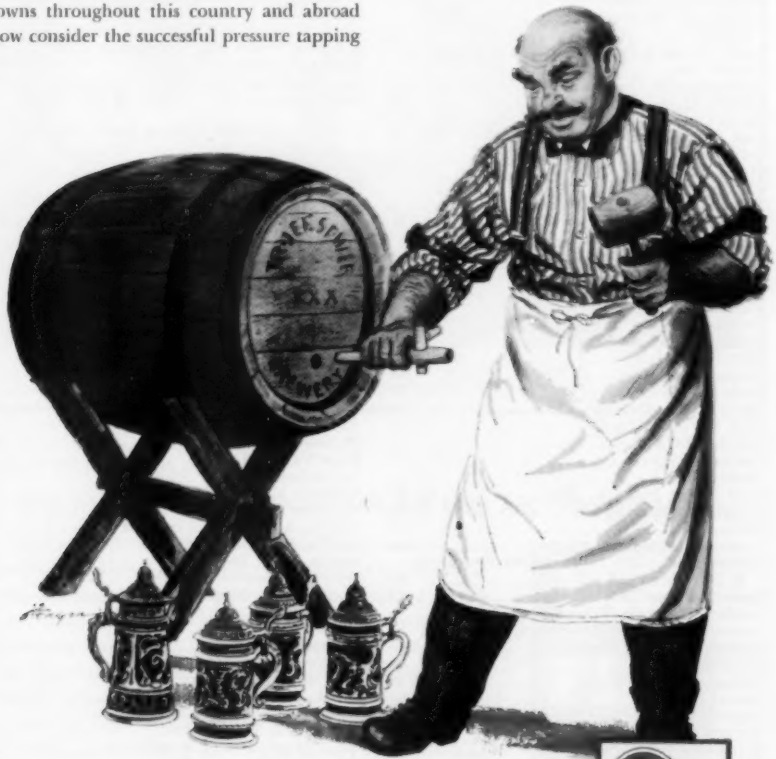

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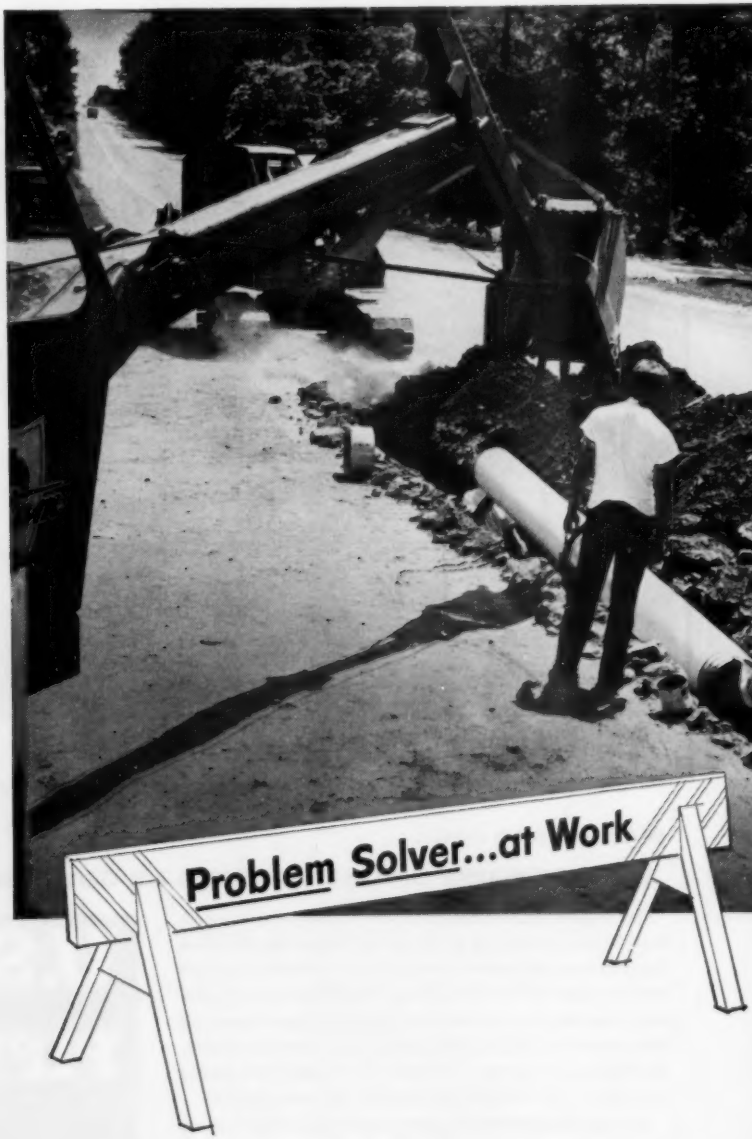

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AWWA SECTIONS

Sep. 12–14—New York Section, at Sagamore Inn, Bolton Landing, Lake George. Secretary, Kimball Blanchard, Rensselaer Valve Co., c/o Ludlow Valve Co., 11 W. 42nd St., New York 17.

Sep. 12–14—Michigan Section, Kalamazoo. Secretary, T. L. Vander Velde, Chief, Water Supply Section, Michigan Dept. of Health, Lansing 4.

Sep. 12–14—North Central Section, at Hotel Lowry, St. Paul, Minn. Secretary, Leonard N. Thompson, Gen. Mgr., Water Dept., St. Paul 2, Minn.

Sep. 17–19—Kentucky-Tennessee Section, at Hotel Patten, Chattanooga, Tenn. Secretary, J. W. Finney Jr., 553 S. Limestone St., Lexington, Ky.

Sep. 19–21—Ohio Section, at Commodore Perry Hotel, Toledo. Secretary, M. E. Druley, Dayton Power & Light Co., Wilmington.

Sep. 26–28—Wisconsin Section, at Stoddard Hotel, La Crosse. Secretary, L. A. Smith, Supt., Water & Sewerage, City Hall, Madison 3.

Sep. 30–Oct. 2—Missouri Section, at Hotel Governor, Jefferson City. Secretary, W. A. Kramer, Rm. 3, 6th Floor, State Office Bldg., Jefferson City.

Oct. 14–17—Southwest Section, at Marion Hotel, Little Rock, Ark. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 15–16—Canadian Section, Maritime Branch, at Admiral Beatty Hotel, St. John, N.B. Secretary, J. D. Kline, Asst. Mgr. & Chief Engr., Public Service Commission, 62 Lady Hammond Rd., Halifax, N.S.

Oct. 18–20—New Jersey Section, at Hotel Madison, Atlantic City. Secretary, C. B. Tygert, Wallace & Tiernan Inc., Box 178, Newark 1.

Oct. 21–24—Alabama-Mississippi Section, at Battle House, Mobile, Ala. Secretary, Irving E. Anderson, Dist. Engr., Surface Water Branch, USGS, Box 2052, Jackson, Miss.

Oct. 23–26—California Section, at U. S. Grant Hotel, San Diego. Secretary, Henry J. Ongerth, Sr. San. Engr., Bureau of San. Eng., 905 Contra Costa Ave., Berkeley 7.

(Continued on page 10)

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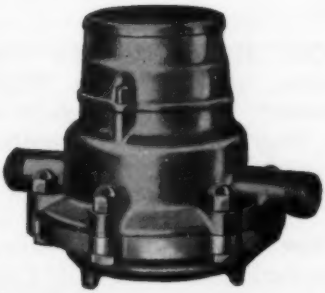

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Coming Meetings

(Continued from page 8)

Oct. 24–26—Iowa Section, at Hotel Fort Des Moines, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

Oct. 24–26—Chesapeake Section, at Sheraton-Belvedere Hotel, Baltimore, Md. Secretary, Carl J. Lauter, 6955—33rd St., N.W., Washington 15, D.C.

Oct. 31–Nov. 2—West Virginia Section, at Hotel West Virginian, Bluefield. Secretary, Hugh W. Hetzer, Engr. Gen. Office, West Virginia Water Service Co., 179 Summers St., Charleston 1.

Nov. 7–9—Virginia Section, at Chamberlin Hotel, Old Point Comfort. Secretary, J. P. Kavanagh, Dist. Mgr., Wallace & Tiernan Inc., 213 Carlton Terrace Bldg., Roanoke.

Nov. 11–14—Florida Section, at Daytona Plaza Hotel, Daytona Beach. Secretary, Jay D. Roth, City Hall, Miami Beach 39.

Nov. 12–14—North Carolina Section, at Hotel Charlotte, Charlotte. Secretary, Wilbur E. Long Jr., 1615 Bickett Blvd., Raleigh.

Nov. 26–28—Rocky Mountain Section, at Broadmoor Hotel, Colorado Springs, Colo. Secretary, Jack W. Davis, Dist. Mgr., Transite Pipe Div., Johns Manville Sales, Inc., Denver, Colo.

Nov. 29–Dec. 1—Cuban Section, at Cuban Society Engineers Bldg., Havana. Secretary, Laurence H. Daniel, Pres., Laurence H. Daniel, Inc., Baratillo 9, Havana.

OTHER ORGANIZATIONS

Sep. 17–21—Annual International Instrument-Automation Conference & Exhibit, New York, N.Y. For information, write Fred J. Tabery, 250 W. 57th St., New York.

Oct. 8–11—Federation of Sewage & Industrial Wastes Assns., Statler Hotel, Los Angeles, Calif.

Oct. 14–17—National Institute of Governmental Purchasing, at Conrad Hilton Hotel, Chicago. A. H. Hall, Exec. Vice-Pres., 1001 Connecticut Ave., N.W., Washington 6, D.C.

Oct. 15–17—Annual Convention, American Gas Assn., Atlantic City, N.J. For reservations, write American Gas Assn. Housing Bureau, 16 Central Pier, Atlantic City, N.J.

Oct. 15–19—American Society of Civil Engineers, Pittsburgh, Pa.

Nov. 12–16—American Public Health Assn., Atlantic City, N.J.

Nov. 27–30—National Chemical Exposition, sponsored by American Chemical Society, at Public Auditorium, Cleveland, Ohio.

1957

Feb. 3–5—Annual Midwinter Conference, Public Utility Buyers' Group, National Assn. of Purchasing Agents, at Brown Hotel, Louisville, Ky. Chairman, L. G. Wiseley, Michigan Consolidated Gas Co., 415 Clifford St., Detroit 26, Mich.

Mar. 25–29—Western Metals Congress & Exhibition, at Ambassador Hotel and Pan-Pacific Auditorium, Los Angeles, Calif. Managing Director, W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, Ohio.

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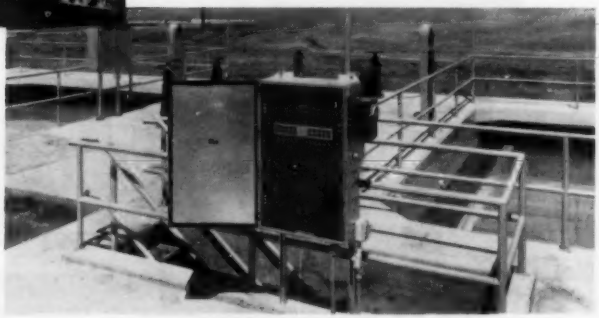

10-STATION WELL FIELD CONTROL with multi-channel scanning eliminates delays in re-starting remote pumps, minimizes capacity loss due to lightning-induced failures for Kansas system. Control center at treatment plant enables remote control and supervision of each well, plus restart programming. Typical of the many Sparton systems enabling better service at lower cost.

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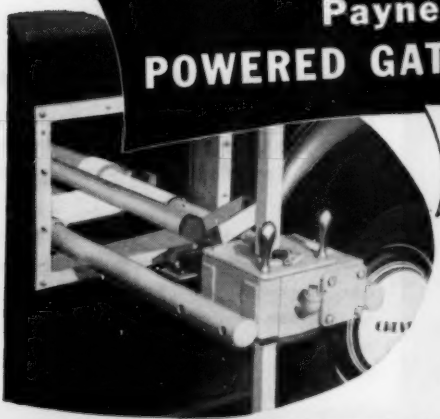

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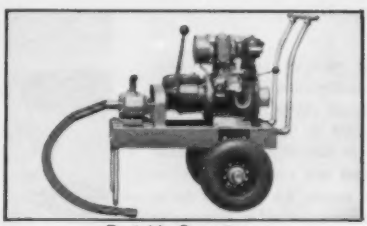
Cut costs and improve maintenance

Truck-Mounted Operator



Portable Operator

Valves should be inspected, opened and closed at least twice each year. You can easily keep this schedule of recommended maintenance . . . within your budget . . . by making every valve Power-Operated with Payne Dean Powered Gate-Operators.

Truck models operate from truck transmission . . . portable units from 3 to 7½ H. P. . . . operate valves and gates as large as 60". Save time . . . reduce cost . . . improve maintenance.

MANUFACTURED BY
PAYNE DEAN & COMPANY
CLINTON, CONN.

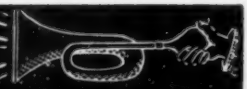
Distributed by

James B. Clow & Sons
INC.
201-299 No. Talman Ave., Chicago 80, Illinois

Please send me information on Payne Dean Powered Gate Operators.

Name.....
Title.....
Address.....
City..... Zone.....
State.....

YOU WERE DOING THIS



WHEN THE FIRST HYDRO-TITE JOINTS WERE BEING POURED -

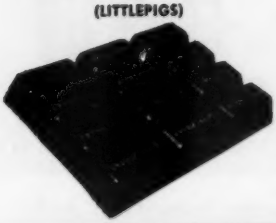
HYDRO-TITE
(POWDER)

HYDRO-TITE

(POWDER)

For over 40 years HYDRO-TITE has been faithfully serving water works men everywhere. Self-caulking, self-sealing, easy-to-use. Costs about 1/5 as much as lead joints. Packed in 100 lb. moisture-proof bags.

HYDRO-TITE
(LITTLEPIGS)



HYDRO-TITE

(LITTLEPIGS)

The same dependable compound in solid form —packed in 50 lb. cartons—2 litters of pigs to the box—24 easy-to-handle Littlepigs. Easier to ship, handle and store.

FIBREX
(REELS)

FIBREX

(REELS)

The sanitary, bacteria-free joint packing. Easier to use than jute and costs about half as much. Insures sterile mains and tight joints.

HYDRO-TITE

HYDRAULIC DEVELOPMENT CORPORATION

A. W. W. A.

HYDRANTS

EASY TO OPERATE AND MAINTAIN

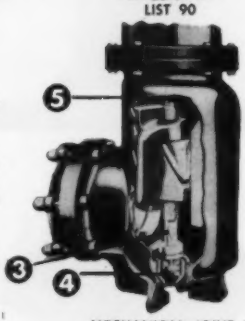
NEW

LIST 90

Ludlow hydrants incorporate all the advantages and meet all the requirements for safety, durability and economy.

HERE'S WHY:

1. **POP-OFF SLEEVE COUPLING:** releases hydrant head from stem in event of traffic damage.
2. **BREAKABLE GROUND LINE FLANGE** eliminates digging.
3. **NO FLOODING.** Closed hydrant remains locked—even in event of traffic accident.
4. **NO FREEZING.** Positive drip action, at extreme bottom, assures complete drainage.
5. **90,000 TENSILE STRENGTH** rolled Everdur threaded stem section completely eliminates stem failure.
6. **LESS OPERATING TORQUE.** New, non-binding upper and lower "O" rings trap lubricant . . . assure positive water tight seal . . . require no servicing.



MECHANICAL JOINT END

THE RESULT: LOW INITIAL COST—YEAR AFTER YEAR—OF TROUBLE-FREE SERVICE.

Ask for Bulletin 54-H

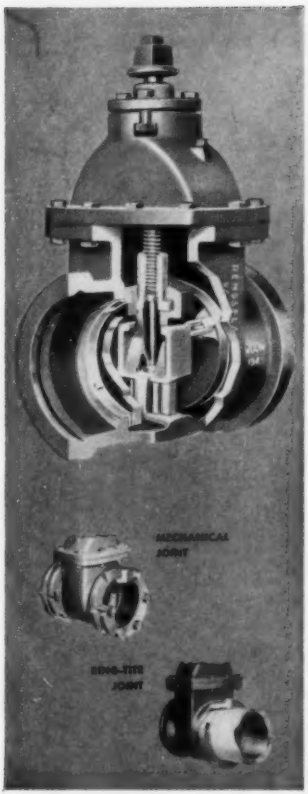
"NO POSSIBLE DIFFERENCE IN FIRST COST CAN OVERBALANCE THE PERPETUAL ECONOMY OF QUALITY."

15

THE LUDLOW VALVE MFG. CO., INC. TROY, N.Y.

TRADE LUDLOW MARK

GATE VALVES • FIRE HYDRANTS • SQUARE BOTTOM VALVES
CHECK VALVES • TAPPING SLEEVES • AIR RELEASE VALVES



A. W. W. A.
VALVES

It costs more to dig up a valve than it does to be sure that the valve is right in the first place. Rensselaer A.W.W.A. Valves have been giving satisfactory service in hundreds of cities for many years, and there are many "reasons why."

The well known Rensselaer wedge mechanism, for instance, presses the gates firmly against the valve seats on closing, but on the first turn of the opening, the wedging mechanism is released and the gates are free.

The generous use of solid bronze, the rust proofing and the simplicity of servicing make for long life and low maintenance. All parts are interchangeable and accurate because of the precision casting and machining.

Only two types of valve ends are shown. All types are available together with tapping valves and other accessories.

The names, Ludlow and Rensselaer mean the same today that they have during your lifetime. The desire to serve the Water Works Field in person —in research and design and in prompt delivery of original equipment and spare parts for all products has not changed. On the other hand, our ability to serve has at least doubled.

16

Rensselaer
VALVE CO. **TROY, NEW YORK**

DIVISION OF
THE LUDLOW VALVE
MANUFACTURING CO., INC.

GATE VALVES • FIRE HYDRANTS • SQUARE BOTTOM VALVES
CHECK VALVES • TAPPING SLEEVES • AIR RELEASE VALVES

Is *Water shortage*

endangering the future of your community?

Badger Water Meters conserve present supplies by giving an exact accounting of usage and waste

Caught in a two-way squeeze between fast-growing population and booming industry, many communities suddenly find themselves with outmoded water facilities. The time to act is NOW if declining water supplies threaten the future of your community. Metering *all* water is the first logical step towards conserving present supplies . . . recording *where* and *how much* is used. Fair rates for all help keep water departments *self-supporting*. Safeguard tomorrow's water needs TODAY.

• For complete information on how metering can insure the future of your community, contact your Badger Meter salesman or write us direct:

Badger Water Meters

Water is Vital

Badger Meters have conserved it for 50 years

BADGER METER MFG. CO. • MILWAUKEE 45, WISCONSIN

tomorrow is too late!

Call in National today!

Dirty, clogged water mains are a serious—dangerous threat to any fire fighting organization. Low water pressure caused by incrusted pipes often makes the difference between minor damage and major conflagration. Yes, dirt can mean disaster. Your community deserves the extra-protection of clean water mains.

And, National with almost a half-century of cleaning experience can guarantee restoration of any water main to at least 95% of its original rated capacity!

Call National today—tomorrow could be too late!

Call in National today!

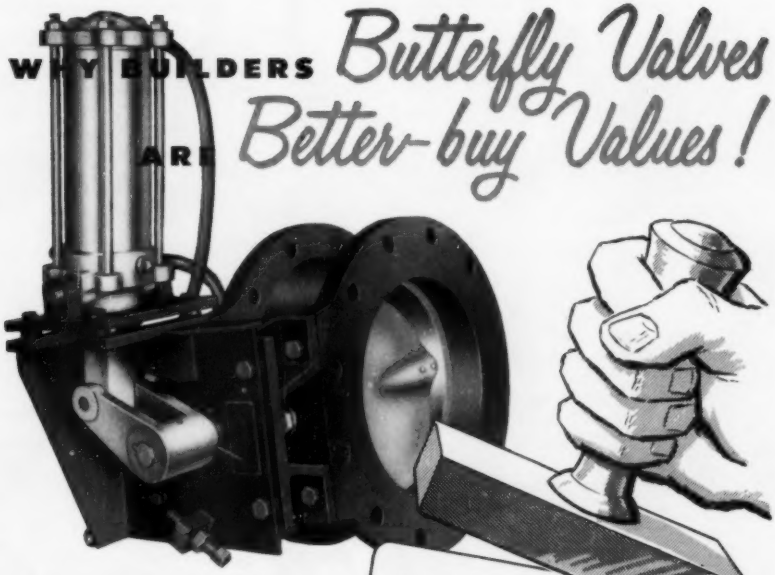
NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

ATLANTA, GA; 333 Candler Building • BERKELEY, CALIF; 905 Grayson Street • DECATUR, GA; P. O. Box 385 • BOSTON, MASS; 115 Peterboro Street • CHICAGO; 122 So. Michigan Avenue • ERIE, PA; 439E. 6th Street • FLANDREAU, S.D; 315 N. Crescent Street • KANSAS CITY, MO; 406 Merchandise Mart and 2201 Grand Avenue • LITTLE FALLS, N.J; BOX 91 • LOS ANGELES; 5075 Santa Fe Avenue • MINNEAPOLIS, MINN; 200 Lumber Exchange Building • RICHMOND, VA; 210 E. Franklin Street • SALT LAKE CITY; 149–151 W. Second South Street • SIGNAL MOUNTAIN, TENNESSEE; 204 Slayton Street • MONTREAL, CANADA; 2032 Union Avenue • WINNIPEG, CANADA; 576 Wall Street • HAVANA, CUBA; Lawrence H. Daniels, P. O. Box 531 • SAN JUAN, PUERTO RICO; Louis F. Caratini, Apartado 2184.

WHY BUILDERS ARE

Butterfly Valves Better-buy Values!



AWWA C-504-55T

ANOTHER B·I·F Blue Chip PRODUCT

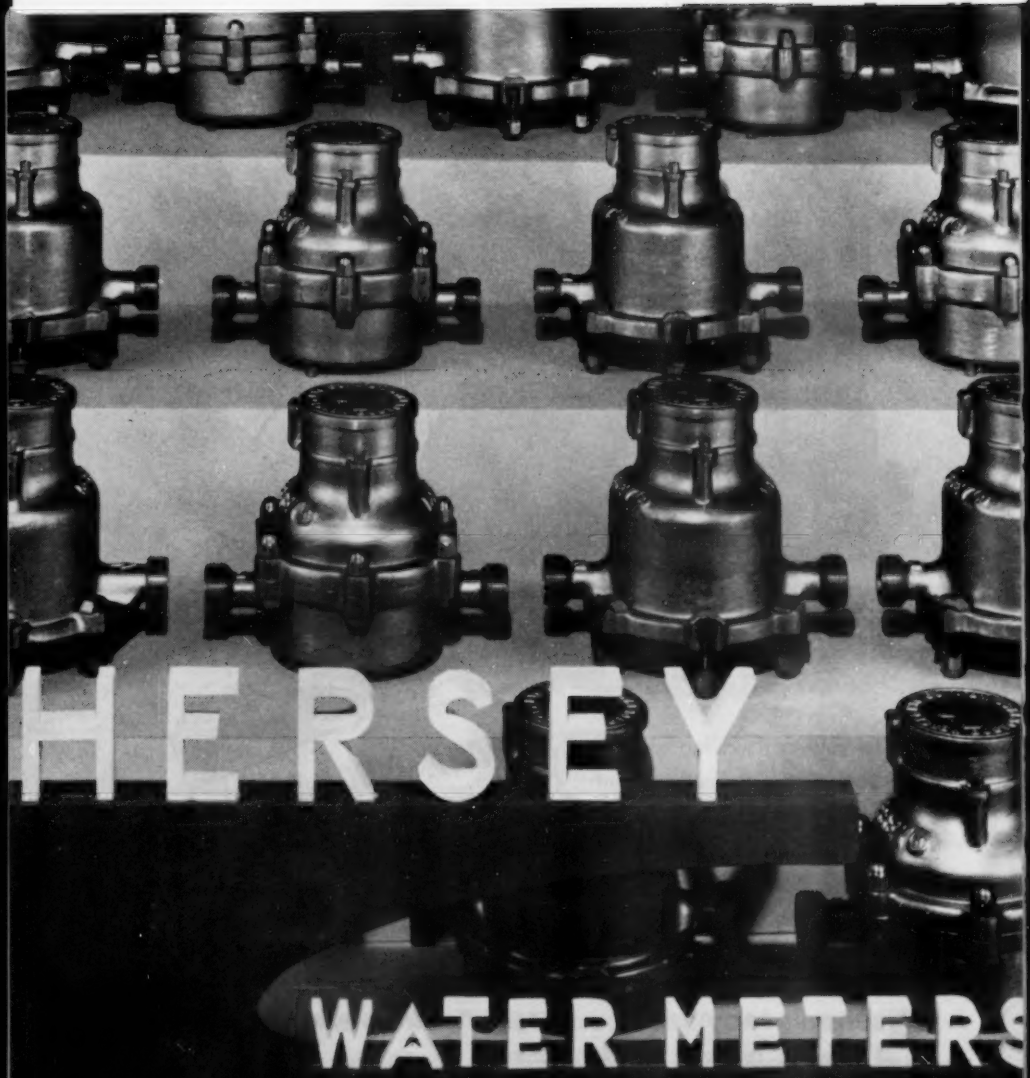
The country's leading consulting engineers, water works plant operators, and water works equipment manufacturers . . . combining their extensive design, manufacturing, installation and operation experience . . . have prepared exacting specifications for rubber-seated Butterfly Valves. **BUILDERS-PROVIDENCE** Butterfly Valves conform to these specifications and offer the following superior features:

- √ Extra-rugged body construction.
- √ Extra large diameter, stainless steel shafts.
- √ Heavier, larger, longer bearings reduce unit bearing load.
- √ Heavier, sturdier vanes.
- √ Operators matched to valve . . . to meet job torque requirements and *minimum AWWA Specs.*

Builders Butterfly Valves fully comply with AWWA STANDARDS to make them BETTER-BUY VALUES. Request Bulletin 650-L1. Write to BUILDERS-PROVIDENCE, INC., 365 Harris Ave., Providence 1, R. I. . . . division of

B-I-F INDUSTRIES
PROVIDENCE, RHODE ISLAND
METERS FEEDERS CONTROLS

BUILDERS-PROVIDENCE, INC. • PROPORTIONEERS, INC. • OMEGA MACHINE CO.



The constantly increasing demand for

HERSEY WATER METERS

clearly demonstrates that they meet the exacting requirements of experienced water works engineers who are primarily interested in low maintenance costs and trouble free accurate registration.

It's the life of a meter that counts — not the cost.

HERSEY MANUFACTURING COMPANY

SOUTH BOSTON, MASS.

BRANCH OFFICES: NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA — DALLAS — CHICAGO
SAN FRANCISCO — LOS ANGELES

AMERICAN FERROFILTER

Installation of "American" Ferrofilters and "American" Double Suction Split Case Pumps at Columbus, Indiana Water Plant • Consulting Engineers, Henry B. Steeg & Associates, Inc., Indianapolis, Indiana.

Independent tests and observations of "American" Ferrofilter operation at the Columbus, Indiana water plant show reduction to .15 ppm on 1.8 MGD loading/filter. (Units are rated 1.5 MGD.) Even on excess loading of 2.5 MGD/filter with all six wells on, iron reduction was still getting down to .2 ppm.

The "American" Ferrofilter is a contact filter that offers many advantages as a complete process or as a preliminary process—for the removal of iron, manganese, carbon dioxide, and other dissolved gases and odors, in one simple operation. It combines fundamental processes and design in an effective and economical treatment plant. Utilizes fine media in open aeration. Can be backwashed to remove any excess accumulation, leaving the filter in condition for another cycle. In most cases, it eliminates the need for a sedimentation tank or sand filter.

Write for Bulletin No. 252B or for specific information relating to your application.

Utilize our experience in engineering design and manufacture of field-proved equipment and pumps for water and waste treatment.

AMERICAN WELL WORKS

IN OUR 80TH YEAR
112 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH - ENGINEERING - MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

PDM
WATER STORAGE TANKS

DEPENDABLE WATER STORAGE

for **BETTER WATER SERVICE**

—to communities and industries everywhere

PITTSBURGH •DES MOINES

- *Elevated Steel Tanks*
- *Reservoirs*
- *Standpipes*

The requirements of the consumer for safe, dependable water supply at constant pressure around the clock are met with maximum efficiency and economy by PDM steel storage units—available in a wide range of elevated steel tank types, and all sizes of steel reservoirs and standpipes for service where natural elevations are adequate. ● Our experience is at your service in consultation. Our craftsmanship and guarantee of satisfaction are part of every job. Estimates and quotations provided promptly on request.

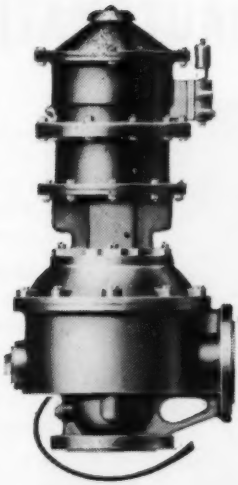
Write for our brochures on PDM Elevated Tanks, and Reservoirs.

PITTSBURGH • DES MOINES STEEL CO.

Plants at PITTSBURGH, DES MOINES, SANTA CLARA, FRESNO, and CADIZ, SPAIN

Sales Offices at:

PITTSBURGH (25). . . . . 3424 Neville Island
NEWARK (2) . . . 221 Industrial Office Bldg.
CHICAGO (3) 1228 First National Bank Bldg.
LOS ANGELES (48). . . . 6399 Wilshire Blvd.
DES MOINES (8). . . . . 925 Tuttle Street
DALLAS (1) . . . . 1229 Praetorian Building
SEATTLE . . . . . 532 Lane Street
SANTA CLARA, CAL. . . . . 631 Alviso Road
MADRID, SPAIN . . . Diego DeLeon, 60



New Simplex Type CCAV Valve. Combination controlled-closing and vacuum-breaking valve.

ONE 4-INCH CONNECTION to your main pipe line...

PREVENTS { **surge rupture** / **vacuum collapse**

Why take chances? No matter what the safety factor, surge and hammer can play some dirty tricks . . . rupture lines, blow out packing, fracture valves. And if the line breaks or is drained rapidly, it can collapse from vacuum.

Simplex Type CCAV is a new combination! A controlled-closing and vacuum-breaking valve to protect your lines against both of these dangers. It's easily installed, moderately priced, positive-acting.

When lines are being filled, Type CCAV Valve vents air to prevent binding, controls transfer time to prevent surge damage. Timing can be quickly set from a few seconds up to well over ten minutes—as dictated by site requirements. If hammer is excessive, Type CCAV automatically discharges water . . . extra protection for costly lines and fittings.

When lines are subject to collapse from rapid draining or line breaks, the Simplex CCAV acts quickly . . . breaks the vacuum for maximum safety.

WRITE FOR FREE BROCHURE

SIMPLEX VALVE & METER COMPANY
DEPT. JA-9, 7 E. ORANGE ST., LANCASTER, PA.

SIMPLEX®

VALVE AND METER COMPANY

EAST AURORA GOES "AUTOMATIC"

AUTOMATIC HARDNESS TESTER on each softener makes soap tests at required intervals. When the water tests hard —regardless of the volume treated—the tester automatically activates the multiport valve that regenerates the softener . . . insuring maximum runs and uniformly soft water despite variations in wells.

AUTOMATIC MULTIPORT VALVE, being checked by operator Bob Fox, takes a softener out of service, backwashes, regenerates and rinses the bed and returns the unit to service —smoothly and automatically—with no attention or supervision.

AND CUTS SOFTENING COSTS

When population jumped to 6,800, East Aurora increased pumpage by 72% from 320,000 to 550,000 gpd. Even at this increased volume, they cut salt costs $4000 a year! They also ended a red-water problem by reducing iron from 1.3 ppm to 0. And they use the *same manpower!*

HOW WAS IT DONE? The increased volume and salt savings were accomplished by using Permutit Q, a high-capacity ion exchange resin with low salt consumption. The iron problem was solved with two Permutit filters. Manpower was not increased because the automatic hardness testers eliminated manual testing. And the efficiency of Permutit's automatic multiport valves frees the operators for other plant duties.

WHY PERMUTIT? "We started with Permutit equipment in 1935, and it worked out so well that we called on Permutit again for our 1950 expansion," says Village Engineer E. J. Maurer.

Permutit will work with you to modernize your present plant or to plan a new one. Call us early in the planning so we can be of most help. The Permutit Company, Dept. JA-8, 330 West 42nd Street, New York 36, N. Y.

A 51% increase in population caused East Aurora, N. Y. to expand and modernize its water works. Wooden structure (left) was replaced by a modern brick building which contains the latest in water conditioning equipment.

PERMUTIT®
WATER CONDITIONING
Equipment • Resins • Experience

CALMET after CALMET,

City after City... Year after Year

MAXIMUM REVENUE

MINIMUM UPKEEP

STANDARDIZE ON
CALMET WATER METERS
TODAY!

MANUFACTURED BY

WELL MACHINERY
& SUPPLY CO., INC.

FORT WORTH, TEXAS

Here's how an "accident" proved the ruggedness of the

F & P CHLORINATOR

Here's a true story of how one user decided the modern, rugged Fischer & Porter Chlorinator was his best buy.

"I was impressed with the F&P Chlorinator the minute your field engineer arrived."

"He pulled up to a loading dock in a truck and began to unload the chlorinator. When he had it at the back of the truck, he stopped and got back inside the cab as if to get something and then 'accidentally' let the clutch slip. The truck shot forward and the chlorinator toppled off the back of the truck and onto the cement floor."

"For a moment we all thought the equipment would smash into a hundred pieces—but it didn't. That just about sold us on it. Of course, we now realize the 'accident' was all part of the demonstration to show us how tough the F&P Chlorinator is."

No other chlorinator is built this way. No other chlorinator can take such punishment. The light weight, fibre glass cabinet is so rugged even such an "accident" won't harm it.

And what's more this is only one true story of user satisfaction with F&P Chlorinators. Everywhere users are adding their words of praise for this chlorinator.

In addition to the ruggedness of the unit, you get simplified operation, the absolute minimum of maintenance costs. As one user puts it, "We shudder at the thought of overhauling other chlorinator units, but it's a pleasure to bring the F&P unit into the shop. We know it will need very little maintenance work—and any work it does need will be 'child's play' compared to the time and back-breaking labor spent on other chlorinators.

Users are saying these things. If you're not completely acquainted with the Fischer & Porter Chlorinator now is the time to get complete information. It won't cost you a penny, you won't be obligated in any way . . . and if you like we will arrange an on-the-spot demonstration for you anytime, anywhere. Write today for details. Fischer & Porter Company, 986 Fischer Road, Hatboro, Penna.

the big

NO ONE KNOWS America's water problem better than you.

With water consumption today four times greater than fifty years ago . . . and mounting daily . . . your responsibilities are heavier than ever.

Many of you not only must find new sources of water but new ways to conserve your present supply. This calls for the cooperation of an informed and alert public, conscious of your problem and mentally conditioned to help you solve it.

MODERNIZED **cast iron**

squeeze is on!

Here, we can and will continue to help.

Our national campaign, reaching millions, stresses the increasing need for industry and homeowner alike to use water wisely and plan in advance for adequate water facilities. It urges realistic water rates and asks support for the forward-looking legislation and bond issues that will insure a plentiful supply for the future.

It's designed to help America conserve its most precious national resource . . . and keep water flowing, freely and abundantly, for all.

CAST IRON . . . the pipe that's bought on proof, not claims

No other pipe can point to so convincing a record of long life.

For over 70 public utilities in America, cast iron mains laid over a century ago are still giving satisfactory service. This demonstrated record of long life (made in the ground, not printed claims) not only gives the public the dependability it has a right to expect in a water system . . . it saves tax dollars as well. Once in the ground, cast iron serves for generations with minimum maintenance. Cast iron's long term economy pays off!

Today, water officials can rely on even better cast iron pipe. Modernized cast iron, centrifugally cast to be even tougher, stronger, more uniform. And where needed and specified, lined with cement mortar to assure sustained carrying capacity throughout its long service.

You specify wisely and well when you specify cast iron pipe for your water system. The experience of centuries proves you chose the best.

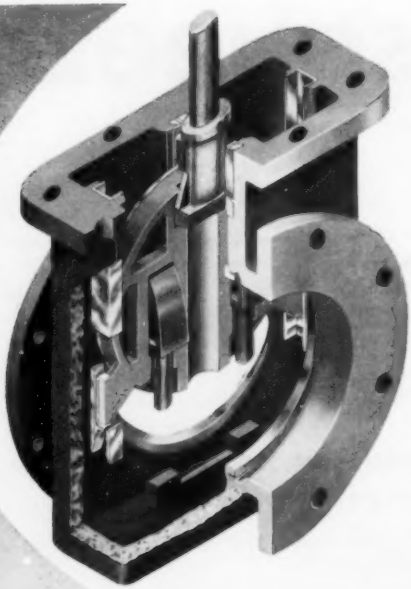
Cast Iron Pipe Research Association, Thomas F. Wolfe, Managing Director, 122 So. Michigan Ave., Chicago 3, Ill.

This gallant old cast iron water main laid in 1850 is still serving and saving tax dollars for the citizens of Buffalo, N. Y.

CAST IRON

The Q-Check stencilled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

pipe FOR MODERN WATER WORKS



DOUBLE SQUARE BOTTOM

GATE VALVES

When it is desired to install a gate valve for throttling purposes, or in a vertical pipe line, M & H double square bottom valves have many important advantages.

When valve is opened, each of the three shoes on both discs immediately contact the feathered edge of the tracks. These three contacts result in the disc being eased away instantly from the seat. The shoes then ride the tracks squarely and firmly for the full travel of the disc. In closing, discs ride the tracks down to a point exactly opposite the valve seat. At that point, the discs are clear and free to seat by action of the two spreaders, each functioning independently of the other. The tracks are stainless steel channels and the two side shoes are bronze-faced.

M & H double square bottom valve prevents the down stream gate from tilting into the down stream port opening and by chatter or vibration damaging the seat and gate rings. These valves can be installed with either disc on the down stream side.

M & H VALVE AND FITTINGS COMPANY, ANNISTON, ALABAMA

M&H PRODUCTS FOR WATER WORKS • FILTER PLANTS INDUSTRY • SEWAGE DISPOSAL AND FIRE PROTECTION

WORTHINGTON-GAMON

WATCH DOG WATER METERS

The meter used by thousands of municipalities in the U. S.

"Watch Dog" models . . . made in standard capacities from 20 g.p.m. up: frost-proof and split case in household sizes. Disc, turbine, or compound type.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE.

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

WORTHINGTON-GAMON METER DIVISION

Worthington Corporation

296 SOUTH STREET, NEWARK 5, NEW JERSEY

OFFICES IN ALL PRINCIPAL CITIES

NEW *V-notch Chlorinators*
SIMPLIFY *Chlorination*

With the new Wallace & Tiernan V-notch Variable-Orifice Chlorinators:

OPERATION IS SIMPLIFIED as one injector control starts or stops the unit. Chlorine gas is turned on or off automatically.

SETTING FEED RATE IS SIMPLIFIED as one control sets feed rate precisely at both high or low feeds.

INSTALLATION IS SIMPLIFIED as units are shipped ready for operation. No water supply is needed at the chlorinator. A remote injector uses only standard water supply fittings.

MAINTENANCE IS SIMPLIFIED and virtually eliminated. All parts are corrosion resistant, mounted in an attractive modern cabinet.

For full details on manual or automatic proportional V-notch Chlorinators, contact your W&T representative, or write to the address below.

A New Development from Wallace & Tiernan Research

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

S-112

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 48 • AUGUST 1956 • NO. 8

75th Anniversary Greetings to AWWA

Greetings received on the occasion of the Association's 75th anniversary and read on May 10, 1956, at the anniversary session of the Diamond Jubilee Conference, St. Louis, Mo.

From the President of the United States

PLEASE EXTEND MY WARM GREETINGS TO ALL ATTENDING THE CONVENTION CELEBRATING THE SEVENTY-FIFTH ANNIVERSARY OF THE AMERICAN WATER WORKS ASSOCIATION.

INCREASING POPULATION AND THE DEVELOPMENT OF NEW HOME AND INDUSTRIAL AREAS PRESENT NEW OPPORTUNITIES TO THOSE IN YOUR FIELD. BY DISSEMINATING INFORMATION ON IMPROVED METHODS AND PRODUCTS, THIS MEETING, I AM CERTAIN, WILL ASSIST ALL OF YOU IN YOUR EFFORTS TO MEET SUCH OPPORTUNITIES EFFICIENTLY. IN THESE EFFORTS ALL OF YOU HAVE MY BEST WISHES FOR SUCCESS.

DWIGHT D. EISENHOWER

From the Engineers Joint Council

The growth and development of the American Water Works Association, from its inception in 1881 as the organization for the advancement of the knowledge of the design, construction, operation, and management of water works to its present position as the leader in this field, is well known to those associated with engineering.

Engineers Joint Council, of which the American Water Works Association is an active and valued constituent member, is pleased to recognize this year as your seventy-fifth anniversary and desires to extend felicitations on this occasion.

It is our sincere best wishes that your organization will continue to prosper professionally as it has in the past. The engineering profession and the public welfare will be the principal beneficiaries.

THOMAS H. CHILTON, *President*
Engineers Joint Council

From the American Society of Civil Engineers

It is indeed a pleasure to transmit the hearty greetings and best wishes of the American Society of Civil Engineers to commemorate the seventy-five years of fruitful existence of the American Water Works Association.

The Association has achieved a record of distinguished accomplishment in the art of water works development and management. Its contributions to the world and to our civilization have been significant and far-reaching. It is highly appropriate that the Association and its leadership be acclaimed on this Diamond Jubilee occasion.

The American Society of Civil Engineers has valued opportunities for joint effort toward mutual goals, and similar cooperative relationships in the future will be welcomed. It is our sincere wish that your 75th anniversary meeting will be completely successful and that the Association will continue to enjoy the productiveness and progress that has characterized its first three-quarters of a century of service.

E. R. NEEDLES, *President*
WILLIAM H. WISELY, *Secretary*
American Society of Civil Engineers

From the American Public Health Association

The American Public Health Association is happy to have the opportunity to extend its felicitations to the American Water Works Association upon the occasion of its seventy-fifth anniversary. The contribution of the American Water Works Association to the improvement of water works practice is notable and there is equal cause for satisfaction in the concomitant strengthening of public health defenses produced by the formulation of standards of water works operation.

As an exponent of the essential role of water supply services in our civilization, the American Water Works Association has played a major part in educating the public, official bodies, and industrial concerns to the importance of an adequate and safe water supply. It has promulgated and staunchly supported efforts to improve the technical competency and efficiency of water works staffs. Its contributions have received international recognition.

The American Public Health Association has enjoyed many fruitful years of cooperative action with the American Water Works Association. It regards with pride the many years of united effort in the development of standards for

laboratory procedures and the successive editions of the authoritative laboratory volume now bearing the title, *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.*

The American Public Health Association congratulates the Board of Directors, Harry E. Jordan, Secretary, and his staff, and the 10,000 members of the American Water Works Association (many of whom are also members of this Association) for these seventy-five years of growth and accomplishment, and extends its best wishes for continued progress and contributions.

REGINALD M. ATWATER, *Executive Secretary*
American Public Health Association

From The Institution of Water Engineers

On this, the seventy-fifth anniversary of the founding of the American Water Works Association, the president, council, and members of the Institution of Water Engineers send you their heartiest congratulations and best wishes.

They are happy to see the Association flourishing as it goes forward towards the completion of its first century, and they sincerely hope that it may long continue the valuable services which it is rendering.

The Association's recent action in electing Mr. H. F. Cronin, C.B.E., M.C., M.I.C.E., a past president of the Institution, to Honorary Membership has delighted members of the Institution throughout the world.

They have asked Mr. Cronin to bring with him to your meeting this expression of friendship and goodwill, and to present it to your president in the name of the Institution.

W. O. SKEAT, *Secretary*
The Institution of Water Engineers

From the British Waterworks Association

It gives me great pleasure to have this opportunity of sending a message to the American Water Works Association.

On behalf of the British Waterworks Association and of the whole of the water supply industry in the United Kingdom, I send our congratulations to the American Water Works Association on the Association's 75th birthday. We wish your Association many happy returns of the day.

We are naturally and justifiably proud of the common ties of language, race, and way of life which bind our two peoples together. It is with great interest that we on this side of the Atlantic follow the news of American people and their life and activities.

We therefore share with you your happiness in reaching this milestone of 75 years of progress.

For the future we wish the American water works industry every success in ever greater achievements; to the American Water Works Association we

wish growing strength; to all engaged in the American water works industry we wish every happiness that employment in this great industry of water supply can give.

Lastly, I would like you to know how proud we are of the honour which your Association has decided to bestow upon our well-beloved colleague Mr. Henry Cronin. This most distinguished ambassador of the water supply industry I have asked to carry to you this message and our very best wishes.

R. C. YATES, *President*
British Waterworks Association

From the Dutch Government Institute for Water Supply

Noting that your Association celebrated its 75th anniversary, I beg to congratulate your fine organization with this remarkable fact.

I admire the work of our American colleagues in the field of water supply and am fully aware of the fact that progress in our technique is for a great part due to their activities.

W. F. J. M. KRUL, *Director*
Government Institute for Water Supply

From the Netherlands Water Supply Association

In the name of the board and the members of the Netherlands Water Supply Association we cordially congratulate you on the occasion of the Diamond Jubilee of your Association.

AWWA inspires us by her scientific approach to water supply technique as well as her promotion of a congenial atmosphere of team spirit among colleagues.

We are sorry that we are unable to assist at your jubilee conference in St. Louis, Missouri, and that we cannot express our feeling of sympathy and solidarity there in person. Our letter, however, has been written in that very spirit.

J. VAN AARTSEN, *President*
HERMAN KAHREL, *Secretary*
Netherlands Water Supply Association

From the Institution of the Dutch Waterworks

THE INSTITUTION OF THE DUTCH WATERWORKS, KIWA, CONGRATULATES YOUR ASSOCIATION VERY HEARTILY WITH YOUR DIAMOND JUBILEE.

J. E. CARRIERE, *General Manager*
Institution of the Dutch Waterworks KIWA

75 Years of Improvement in Water Supply Quality

Abel Wolman

A paper presented on May 10, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Abel Wolman, Prof. of San. Eng., Johns Hopkins Univ., Baltimore, Md.

IN 1798, readers of the *Philadelphia Monthly Magazine* (*1*) were advised:

> Pure water . . . is the best drink for persons of all ages and temperaments. By its fluidity and mildness it promotes a free and equable circulation of the blood and humours through all the vessels of the body, upon which the due performance of every animal function depends, and hence water-drinkers are not only the most active and nimble, but also the most chearful and springly of all people. . . . But to delicate and cold constitutions, and to persons unaccustomed to it, water without wine is a very unproper drink.

Centuries before this, even, water drinkers may have been complimented in much the same fashion, and water purveyors placed on their mettle to provide this commodity in such a manner as to make it of the maximum usefulness and satisfaction to man. Conscious technological and scientific effort toward these objectives is more than 75 years old. With the creation of the American Water Works Association in St. Louis, Mo., 75 years ago, however, action toward these age-old objectives was given new stimulus and a new and continuing forum.

The increasing importance of water supply quality since that time may be traced in any of the several excellent summaries now available. The exciting and detailed expositions by M. N. Baker (*2*), Harry E. Jordan (*3*), and perhaps a dozen others, have placed in the record the significant advances in water supply quality and treatment in this three-quarters of a century of important progress.

When confronted, therefore, with the task of reviewing this progress once more, the simple repetition of these accomplishments, numerous and exciting as they are, would have little appeal to the reader and even less to the writer. We might repeat with Jordan (*3*) that "The history of water supply in the United States is an epic of constant progress and achievement." And, bringing his figures up to date, we might point out that in 1850 there were only 68 cities with planned water supplies, while today, in 1956, there are over 17,000 urban supplies in operation. The recapitulation of the changes in water treatment from slow sand filtration through rapid sand filtration and of the struggles concerning coagulation and chlorination would still stir up reminiscences and inspiration. References to current texts, far more elaborate than the present contribution, would better supply the student in this field, however, with

myriads of detail concerning processes, issues in debate, scientific progress, and personalities.

These texts would likewise recall that in this period the improved sanitary quality of the public supplies has brought about one of the most dramatic improvements in public health that the world has ever known. Typhoid fever alone declined from 75–100 deaths annually per 100,000 persons to less than 0.1 in 1955. Today the average water practitioner accepts and operates standard water treatment processes of effective coagulation, sedimentation, filtration, and disinfection as if they had always existed. Sometimes he is even unaware of the public battles, the court procedures, the contesting scientific judgments, the extensive laboratory studies, and the resistant public opinion upon which these milestones rest.

Great Investigators

Throughout all of these accomplishments, the great giants of the water works industry moved forward with clarity and speed. It is not amiss to recall today the significance of James P. Kirkwood, the Hyatts, Allen Hazen, George W. Fuller, Paul Hansen, G. C. Whipple, Robert Spurr Weston, and George A. Johnson. This is an appropriate place also to point out that this galaxy of stars owed their inspiration to the great leader of environmental sanitation of the period, William T. Sedgwick. It is with no little pride that the author observes that Sedgwick emigrated from Johns Hopkins University to the Massachusetts Institute of Technology, which now claims him exclusively as its own.*

* To set the record straight, Sherman Chase of Boston, the next speaker on the program, pointed out that Sedgwick went to Johns Hopkins from Yale.

The history of chlorination, since 1908, has likewise been marked by a succession of dramas. Here, too, detailed summaries of this progress have fortunately been preserved in the literature through excellent monographs by Faber and others. The work of E. B. Phelps, Joseph W. Ellms, S. J. Hauser, Linn H. Enslow, the author himself, and others, placed chlorination practice upon a national basis and hastened its almost universal adoption. This evolution was not without its conspicuous opponents, particularly in Massachusetts, where it was claimed that the water supply sources in that state had not been polluted and that chlorination was therefore not needed. Even today there remain certain nostalgic practitioners in that region who still pursue the will o' the wisp of the "virginal innocence" of surface sources of water supply, which contraindicates any urgent necessity for treatment.

Struggle for Quality

Of greater interest in some respects than the rehearsal of these accomplishments is the review of the changes, both in quality and in treatment, through which public water supplies have moved over the last 75 years. Blake (*4*) has recently done a great service to the water works industry by reviewing the history of the urban water supply problem in the cities of Philadelphia, New York, Boston, and Baltimore. This volume provides entertaining and convincing illustrations of the changes which have taken place in both ownership and quality of the supplies of these great cities. In the city of Baltimore, for example, after years of struggle, the consumer was still using the Jones Fall supply, which was described by one of its opponents as being introduced "not to water the city,

but to whitewash the Know-Nothing party." It was described as a water furnished "from manured and impure watersheds" in which "the organic matters thus derived, undergoing decomposition, breed myriads of vegetable and animal germs, or infusoria, which, drying, and in their turn decomposing, give rise to the putrescent odor and tastes so noticeable in hydrant water during the first weeks of the heated term" (*4*).

Chemical analyses of waters shed little light upon such problems as these, even though strenuous and sometimes successful efforts were made to glean from the standard chemical analysis of the day indications of water supply quality and means of correction.

In 1896, for example, the Baltimore city chemist reported 88 complete analyses of water from house taps in all parts of the city. Forty of these were analyzed in detail, with the following results (in parts per million): volatile solids, 36.2; mineral solids, 38.0; total solids, 84.2; chlorides, 6.28; free ammonia, 0.043; albuminoid ammonia, 0.08; nitrogen from nitrates, 0.129; nitrogen from nitrites, none. The chemist judged (from what constituted at that time the standard for good potable water) that the water supply of the city of Baltimore had been chemically good throughout the year and "satisfactory and considerably above the normal in quality." He goes on to declare that "the unpleasant (fishy) taste, which had been a source of annoyance to the public during the months of November and December, whilst no doubt very disagreeable, was in itself perfectly harmless from a sanitary standpoint."

The use of such data, necessary in the absence of significant biological, physical, or other chemical information, led of course to tortuous techniques and explanations for objectionable water quality. The water served to Baltimore at that time was physically objectionable, was obviously bacterially contaminated, and, from a standpoint of taste and odor, was at regular intervals unpleasant to the consumer. On the basis of the chemical analyses already presented, however, it would compare very favorably with a totally different commodity furnished in 1955 in the same city. In 1955 the finished filtered water showed the following comparable constituents (in parts per million): volatile solids, 27.6; total solids, 90.8; nitrates, 0.4; chlorides, 8.0. These comparisons merely confirm the conclusion that the use of chemical analyses alone left much to be desired as a means of assessing comparative water quality. Their hold on the water diagnostician, however, persisted in some areas in this country; in these areas they remained almost the *sole* basis of assessing water quality until the late 1920's.

This is further exemplified by the report submitted in 1881 to the Joint Standing Committee on Water for Boston, Mass. (*5*) by perhaps the most distinguished chemist of his time, Ira Remsen, later president of Johns Hopkins University. The following quotations from Remsen's report are worth recording for permanent reference.

> As there is a great deal of misconception in regard to the value to be attached to chemical analyses of drinking waters, a few words of explanation may not be considered out of place. The [type of contamination] most frequently to be feared . . . is sewage. This cannot be detected directly by means of chemical analysis, nor by any other means; but, nevertheless, a fairly accurate judgment may be formed in the case of a suspected

water by taking into consideration the results of the analyses, as well as the conditions surrounding the water. If we find a considerable quantity of solid matter in the water, together with an abnormal quantity of chlorine, of nitrates, and of nitrogenous organic matter, the presence of sewage would be suspected. If, then, on examining the surrounding conditions, we should find good reasons for believing that sewage might find its way into the water, the conclusion would be justified that the water is contaminated with sewage matter. Such water should be condemned at once, and no one should be allowed to drink of it under any consideration. . . . Water may, however, become contaminated in other ways, and might easily become contaminated in such a way that chemical analysis would be powerless to detect the foreign material, or, if it should be detected, to determine its nature. The whole subject is, in short, in an unsatisfactory state, and should any one, in the examination of some waters, confine himself to cut-and-dried rules, he would be very apt to come to false conclusions. Common sense is a very essential condition of success in the examination of waters, as well as in most other difficult processes.

Remsen proceeds to make comparisons between the water supplies of Boston and Baltimore. Disconcerting as these comparisons may be, they are repeated here for purely historical purposes.

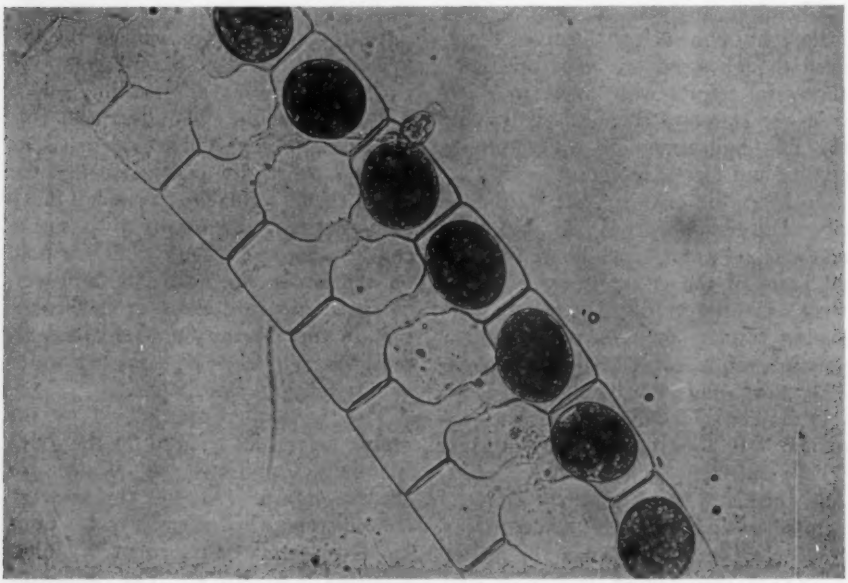


Fig. 1. Early Algae Photograph, Boston Water Works, 1892

Plate which shows Spirogyra chlorophyceae *(conjugating form) was made by George C. Whipple under gaslight.*

It may be instructive to compare the water as it is at present in Farm-Pond with that which I examined last spring in Baltimore. As far as I am able to judge, the taste and odor of the two

waters are identical, only I do not remember that the Baltimore water ever had these as strongly developed as they are in the pond. In every respect the two waters conducted themselves in the same way. When heated, the odor of both was intensified, and the taste of the water on cooling was much improved. On standing for some time, the Farm-Pond water loses its odor and taste, as did the Baltimore water. The only difference which I have observed is this: the Baltimore water when passed through a good large filter of animal charcoal and gravel lost its taste completely, and analysis showed it to be perfectly pure. The Farm-Pond water, however, does not, at least with those filters which I have been able to procure here, lose its taste entirely when filtered, though it is much improved by the process. I should judge that this difference is only one of degree. The Farm-Pond water [was] certainly much worse than the Baltimore water at the time I made my examination.

It is not with malice aforethought that this paper includes Remsen's invidious distinction between the quality of the Boston city water and that of Baltimore. The distinction, apparently so disadvantageous to Boston, might not have been borne out by more modern techniques of examination.

The Boston report of 1881 also makes clear that these problems of water supply quality were handled on a very high level, since not only did the later president of Johns Hopkins University participate, but he extends special thanks to the president of Harvard College, to Desmond Fitzgerald, and to C. W. Andrews—Bostonians all—who assisted him in his activities and provided laboratory facilities.

Tastes and Odors

It was during these early periods that much of the progress was made in the identification of sources and causes of taste and odor, particularly through the highly significant field and laboratory observations made by the distinguished George C. Whipple in his studies of the water supplies of New York City and Boston. Several of the earliest, if not in fact the first, photographs of the now familiar algae forms, which were made in 1892 in the Boston water works at the Chestnut Hill reservoir, are shown in Fig. 1 and 2. They were made almost exactly 65 years ago. There was no

Fig. 2. Photograph of Nauplius of *Cyclops*
Like Fig. 1, photo was made at Boston's Chestnut Hill plant in 1892, by gaslight.

electricity available in Whipple's laboratory, so the photographs had to be taken by gaslight. Considering the difficulties which accompanied the making of these photographs, they are remarkably clear in reproduction and played a highly significant part in subsequent efforts to prevent and to control taste and odor in public water supplies. This phase of water quality probably has greater impact upon consumer reaction than almost any other with which the water producer deals.

Taste and odor problems 75 years ago were very serious because there

were no known corrective measures other than aeration, which too often was relatively ineffective.

The first record of discussions concerning odor problems in an AWWA publication was in the report of the third annual meeting held in Buffalo, N.Y., in 1883. Based on discussions at that time, the troublemakers were undoubtedly algae. Whipple's work demonstrated that algae were responsible for the taste and odor conditions. It was not until 1904 that copper sulfate was announced as an algicide; although copper sulfate was a considerable aid in the control of algal growths, it was only a partial solution to the associated odor problem.

World War I resulted in a tremendous expansion of this country's chemical industry, whose wastes added still further to the growing odor problems. The advent of the automobile resulted in construction of hard-surfaced roads, and rain water washing the macadam roads added phenol and related compounds to the already perplexing odor problems.

In 1924, John R. Baylis, then principal sanitary chemist for the Baltimore Water Department, declared:

> There are objectionable tastes in many of the waters of our country that will always remain objectionable, unless removed. It is the removal or prevention of these that should receive more consideration from our water works officials than heretofore. Changes in our modes of living and this vast amount expended for things that add comfort and pleasure to our lives justify the assumption that we are now ready for more rapid progress in improving the palatableness of our drinking water.

Possessed of such strong beliefs, it was natural that Baylis should turn to activated carbon, because of its potential for removing these objectionable tastes. His work on granular activated carbon at the Chicago Experimental Filter Plant in 1927, coupled with his emphasis on producing palatable water, was the flux necessary to develop a countrywide interest. His early work on granular activated carbon, coupled with his later work on powdered carbon, has resulted in his being affectionately dubbed "Mr. Activated Carbon."

In 1929 George R. Spalding and Paul Tamer, of the Hackensack Water Company, New Milford, N.J., conducted laboratory tests with powdered activated carbon. Results were so encouraging that the first plant test was conducted in March 1930. Within a year, many water plants throughout the country were trying powdered activated carbon, because it could be used without the costly expenditures for additional filters necessary to accommodate the use of granular types. Powdered activated carbon was so successful that today well over 1,200 water treatment plants in this country alone use it for taste and odor control.

Since the advent of powdered activated carbon, many other methods of odor control have been tried. Surviving methods, however, are limited almost entirely to ozone, free-residual chlorination, and chlorine dioxide. Activated carbon still has a major position as a positive method for producing palatable water even under severe conditions. The road to universally palatable water, however, has been only partially traversed, even though suitable control methods are available. Some operators refuse to admit their responsibility to their consumers, while others laugh off complaints, and still others honestly do not know that the water they are delivering is unpalat-

able. John Baylis' statement in 1924 is still applicable in many communities today and is worthy of repetition. "The removal or prevention of [objectionable tastes] should receive more consideration from our water works officials."

Standard Methods of Analysis

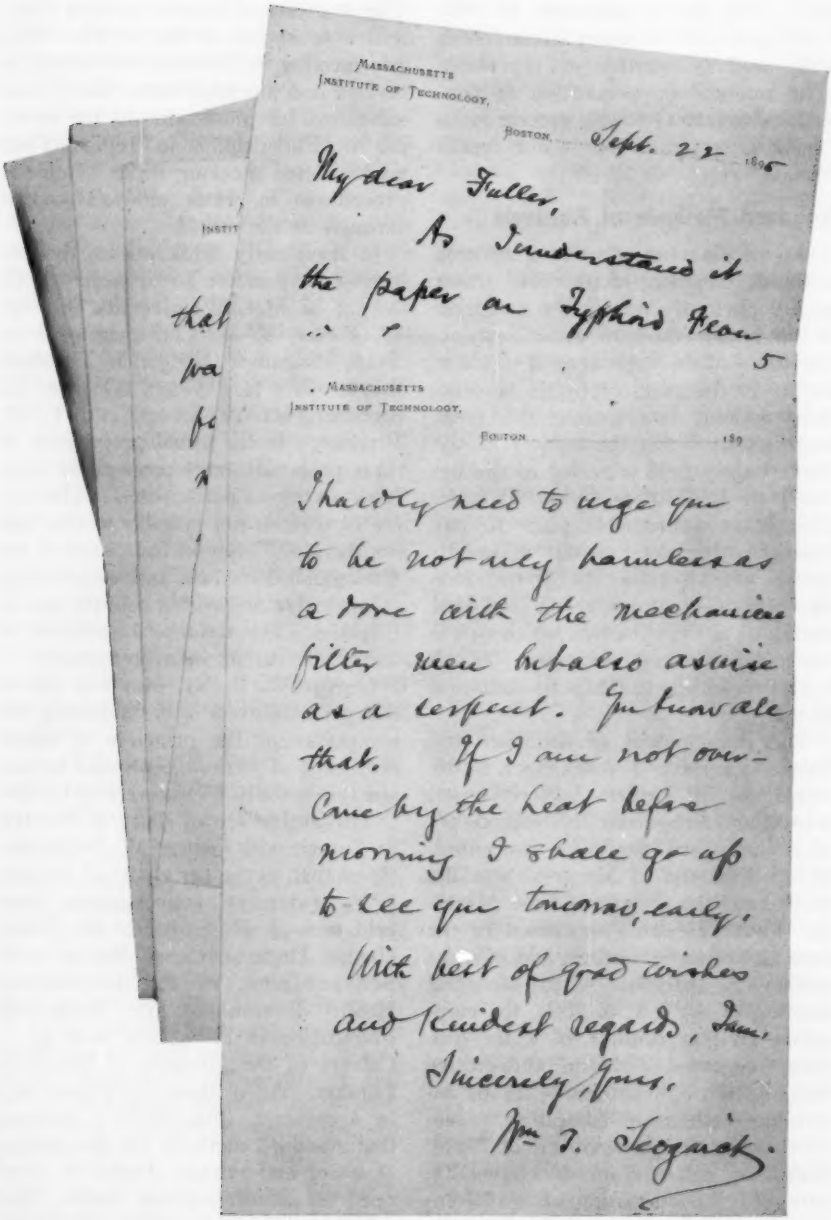
One of the most effective stimulants to the development of improved water quality obviously was in the evolution of standard methods of water analysis. No record of the improvement of water quality in this country would be complete without emphasizing the great contribution which the leaders in the water supply field provided in the period from 1890 to approximately 1898. This is an appropriate place to pay tribute to that great group of investigators who foresaw the tremendous significance of providing a standard technique of examination, which would become a universal language for all water works investigators to learn and to use.

The development of filtration and disinfection methods owes much to the researches of water bacteriologists, who early recognized the essentiality of a standard analytical procedure. Wyatt Johnston of Montreal was the first to call the attention of the American Public Health Association to the necessity of more uniform and efficient methods of analysis. At the Montreal meeting of APHA, in 1894, the committee on the pollution of water supplies suggested a broad cooperative investigation. A subcommittee to determine methods of laboratory procedure, under the chairmanship of W. H. Welch of Johns Hopkins University, extended the discussion at a convention at the Academy of Medicine in New York City, Jun. 21 and 22, 1895. This convention created another committee to report at the APHA Buffalo meeting in 1896 and its report, in revised and amended form, finally was submitted for publication at the meeting in Philadelphia in 1897. Thus was initiated the long series of official procedures in water analysis known throughout the world.

In these early deliberations, the following were active participants: J. G. Adami of McGill University, George W. Fuller, T. M. Cheesman of New York, William T. Sedgwick, Theobald Smith, W. H. Welch, George M. Sternberg, C. A. Smart, and T. M. Prudden. In the initial preparation of these proposals many cooperative laboratory workers participated. The listing of these is not possible in this limited review. They include some of the distinguished medical and bacteriological investigators in this country and in England. The accomplishments of the late 1890's cannot be overestimated.

George W. Fuller, who was one of the prime movers in establishing the acceptance of the principle of standardization of method, continued to pursue this activity for the rest of his life.

The author's own diary of his trip to Europe with George W. Fuller discloses that, in the early part of January 1926, extensive conversations were held with Z. R. Spitta, of the Public Health Department of Berlin; with Selskar Gunn, of the International Health Bureau of the Rockefeller Foundation in Paris; and with H. T. Calvert of the Ministry of Health in London. All of these gentlemen were in agreement with Fuller's proposal that standard methods for the analysis of water and sewage should be developed on an international basis. Most AWWA members know, of course, that this effort, so strongly emphasized



MASSACHUSETTS
INSTITUTE OF TECHNOLOGY,

BOSTON, Sept. 22 1895

My dear Fuller,

As I understand it the paper on Typhoid Fever

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MASSACHUSETTS
INSTITUTE OF TECHNOLOGY,

BOSTON, 189

I hardly need to urge you to be not only harmless as a dove with the mechanical filter men but also wise as a serpent. You know that. If I am not overcome by the heat before morning I shall go up to see you tomorrow early.

With best of good wishes and kindest regards, Sincerely, Yours.

Wm T. Sedgwick.

Fig. 3. Letter from Sedgwick to Fuller, 1895

on the author's trip to Europe in 1926, has not yet reached fruition.

The World Health Organization has now undertaken, however, to explore this task. It has already created a small working group under the chairmanship of F. Wellington Gilcreas, to move toward the development of international standards of drinking-water quality and of approved methods for the examination of water. This working group has already had one session in Geneva, Switzerland, in 1955, and will have a regional session, with many other countries participating, in Manila, Philippine Islands, early in the summer of 1956.

Gilcreas has already prepared for the World Health Organization elaborate data from 71 countries. For the major part the data are scanty in nature, but highly informative as to deficiencies. In brief summary, the findings indicate that no official standards of water quality are generally in use. Methods for the examination of water are almost as lacking in uniformity as are standards for quality. It may be predicted, however, that this operation initiated by the World Health Organization will undoubtedly result in an accomplishment visualized in European negotiations three decades ago by the late George W. Fuller.

He exhibited in this field, as in so many others, an imagination and a courage in undertaking new tasks, the accomplishments of which are as numerous and as significant as those of almost any other contributor. The Louisville and Cincinnati experiments, curiously enough, anticipated a great deal of the knowledge of today. The corps of workers engaged in these enterprises showed remarkable scientific acumen and advanced the science and the art of water purification by more than a century. Only the keenness of their laboratory observations could account for the superb diagnostic values which came from these elaborate studies.

Commercial Equipment

Most of these studies were carried out at a time and with equipment which was dominated by commercial patents and patent-holders. It speaks well for this group of scientific investigators that they were not deterred from undertaking their important tasks by the fact that in many instances they were struggling with proprietary devices already in contest in court and in technological forums.

So strong was this underlying feeling that William T. Sedgwick, one of the supreme public health investigators of his day, felt impelled to write to George W. Fuller, on Sep. 22, 1895, a letter, shown in facsimile in Fig. 3, as follows:

My dear Fuller,

As I understand it, the paper on Typhoid Fever in Lawrence is to be by Copeland and myself jointly, but in any case it seems to me that courtesy, if nothing else, should have led you to consult with me about the matter. However, as you have resigned [from the Lawrence Experiment Station—*Author*] we need not discuss the matter, but I may rather hasten to say that while I congratulate you warmly on the one hand and feel anxious for you (as being more or less in the hands of those money-makers) on the other, I am really *very* sorry to have you resign from Lawrence. Your going will be a real loss to us all and to the work. You have done exceedingly good work at Lawrence and have kept the Station at a high state of efficiency. I feel that you have done honor both to yourself and to the Institute from which you came; and our warmest good wishes will go with you into your novel and difficult undertaking. I hope you will get Weston and take him with you for he seems to be

a fine fellow, and will not easily be hoodwinked.

As to the work I trust that whatever you do or do not do you will remember the Institute and the S.B.H. [State Board of Health] to both of which you owe so much. Especially, I hope you will, if it becomes necessary to make comparisons of any kind with the Lawrence work, do everything in a friendly spirit. It is Massachusetts and its S.B.H. which has made all these other things possible and desirable.

I hardly need to urge you to be not only harmless as a dove with the mechanical filter men but also as wise as a serpent. You know all that. If I am not overcome by the heat before morning I shall go up to see you tomorrow, early.

With best of good wishes and kindest regards, I am,

Sincerely yours,

Wm. T. Sedgwick,

Most members of the profession are aware of the fact that these fatherly pieces of advice were followed. It is well to remember the debt we owe to the omniscient and kindly Sedgwick, and to the rugged, realistic, and acute Fuller. Today one may heartily acknowledge the great contributions to the art of water treatment by the skillful manufacturer, without ignoring the injunctions of Sedgwick that the judicial investigator must forever preserve scientific objectivity and accuracy in the evaluation of any commercial process or equipment.

Future Prospects

M. N. Baker, in his scholarly volume (*2*) on the quality of water, epitomizes the situation in the past in the following terms:

> In the earliest days of the human race, water was taken as found. It might be pure and abundant, plentiful but muddy, scarce but good, or both scarce and bad. . . . Man's earliest standards of quality were few: freedom from mud, taste, and odor.

The fragments presented in this paper illustrate the long road traversed, the great progress made, the ever-tightening criteria of chemical, physical, and biological characteristics, and the rapid trend toward the literal tailoring of water for the domestic, industrial, or farming customer. The requirements become more numerous and more complex.

Simultaneously with these demands, investigators move forward as in the past toward new solutions, new experiments, and the adjustment of old concepts to new challenges. The refining of water proceeds apace with the work of the Geyers, the Hudsons, the Renns, the Thomases, and other unsung heroes in the water purification field.

With the intensification of work on desalting, on the application of fluorides to water, on the re-exploration of the silver salts, and on studies of the viruses, we find ourselves once more on the threshold of a new era. What the future holds, the crystal ball does not disclose, but that it will be an exciting one to review at the hundredth anniversary of the AWWA may be predicted with assurance.

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75 Years of Progress in Water Supply Engineering

E. Sherman Chase

A paper presented on May 10, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by E. Sherman Chase, Partner, Metcalf & Eddy, Engrs., Boston, Mass.

IN his discussion of the past 75 years in the water works field (*see* p. 925) John Murdoch points out how and why the early history of water works in the United States was so dominated by privately owned utilities, when today the large majority of plants are publicly owned. Although many of the early water works were designed and built with the profit motive dominant in the minds of their promoters, the general principles and practices of water works engineering remain substantially the same as they were 75 years ago. This is because many of the fundamentals of mechanics and hydraulics had already been discovered and formulated by scientists and engineers. Although rule-of-thumb methods and amateur engineering were common in many of the smaller systems, competent civil engineering principles were applied to the design and construction of most of the larger systems. It would take too long to list the outstanding engineers and the water systems designed and constructed under their guidance. Many of these men and their contributions are likely to have been forgotten by now; yet their works still stand, and their ideals are imperishable.

Other than Charles S. Storrow's *Treatise on Water Works* of 1835 (*1*) there were, to the author's knowledge, no general and comprehensive books upon water supply engineering published in this country prior to J. T. Fanning's *Practical Treatise on Water Supply Engineering* of 1877 (*2*), and William Humber's review of English practice, *A Comprehensive Treatise on the Water Supply of Cities and Towns*, which was first published in London in 1876 and later in Chicago in 1879 (*3*). The dearth of published information on water works practice and the need for dissemination of knowledge were among the reasons leading to the founding of the American Water Works Association. The papers, reports, and books dealing with water supply engineering published in the past 75 years provide an overwhelming mass of information. Few, indeed, are the problems for which some precedent or solution cannot be found in existing publications.

Supply Sources

Sources of supply remain today as in 1871—namely, surface sources from lakes, streams, and impounding reservoirs, and ground water sources from springs, wells, and infiltration galleries.

Concerning the development of surface sources, the present-day water works engineer is provided with an

accumulation of hydrographic data not available to his predecessor. Topographic maps covering much of the United States now provide the engineer a means of accurately delineating watershed areas. For these data the water works profession owes a deep debt of gratitude to the US Geological Survey. The early engineer was handicapped by the scarcity of such data. John R. Freeman in his *Report on New York City's Water Supply* of 1900 refers to embarrassment in his exploration of possible sources of supply west of the Hudson River for lack of good topographic maps of the areas explored (*4*).

Water works intakes from streams and lakes have changed little over the years. Mechanical screens have been developed and methods of constructing intake tunnels have been modified as the result of electrically powered tools.

The fundamental principles of dam design also have changed very little.

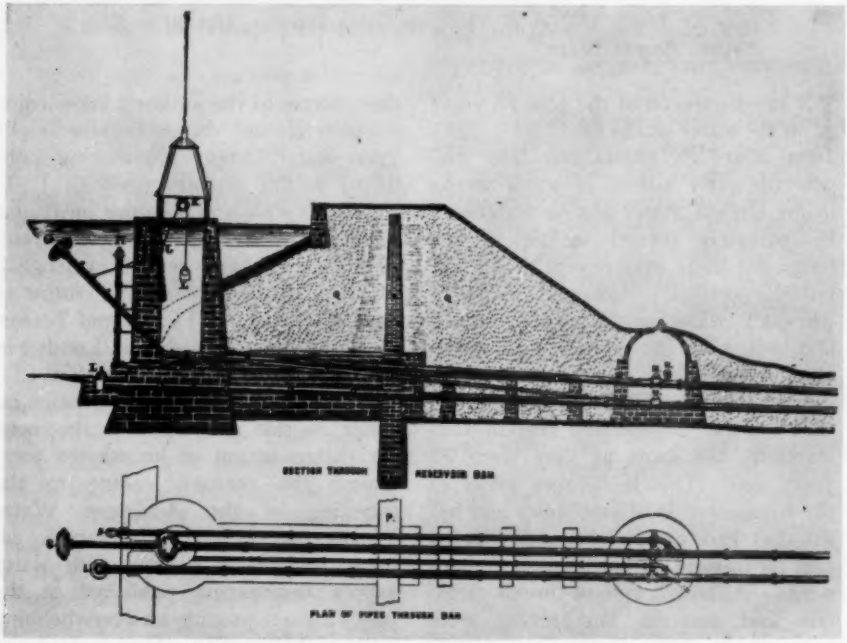

Fig. 1. Masonry-Core Earth Dam

A masonry-core embankment used in an impounding and distributing reservoir at Norwich, Conn., c. 1877, is shown. The engraving is from Fanning (2).

Earth dams are built, as formerly, with an impervious core and selected material on either side of the core, although masonry cores, such as that shown in Fig. 1, are seldom used at present. Knowledge of soil mechanics, a relatively recent technological advance, now aids in selecting materials, in assuring stability, in controlling seep-

age, and in determining the degree of impaction required. The methods of construction of earth dams show the greatest change. Old photographs of earth dams under construction show the embankments teeming with men, and horse- or mule-drawn carts. In 1889, the building of the San Mateo Dam for the Spring Valley Water Works of San Francisco involved the use of 1,000 men with wheelbarrows to distribute concrete. Today such embankments would be built with power shovels, bulldozers, scrapers, massive trucks, motorized wagons, and the like.

Masonry dams, once built largely of stone, are now constructed of concrete. The sizes of these dams have become far greater than those early dams of the New York and Boston systems. The methods of construction have also changed, through the universal use of power equipment and new techniques in concrete manufacture and control.

In the early days of dam building, overtopping and structural failure occurred frequently. One of the historical failures was that of the South Fork Dam at Johnstown, Pa., in 1889. Another more recent failure was that of the St. Francis Dam in California in 1928. Dreadful as were the results of these and similar calamities, they have served useful purposes, for they led to improvements in the design and construction of dams, and the establishment of regulatory supervision thereof.

Ground water supplies were usually utilized by the smaller towns. Sources frequently consisted of springs, from which the water could be conducted by gravity to the distribution system, or gangs of small-bore shallow tubular wells sunk into glacial gravel, from which the water was withdrawn by suction pumps. Deep wells of larger bore were developed in areas where limestone or sandstone strata were water bearing. When the water table was too low to permit suction lift, water was pumped from such wells by means of submerged plunger pumps actuated by long sucker rods connected to motors at the well head. At one time, the use of air lift for raising water from deep wells became somewhat popular. Of relatively recent origin is the so-called "gravel-packed" well which is perhaps the most commonly adopted type today, where ground water conditions warrant. The use of submerged multibowl turbine pumps has made these wells eminently practicable. The large shallow dug well and the infiltration gallery, both quite widely adopted in the past, now seem out of favor. Although recharge of ground water supplies by flooding overlying pervious areas with surface water has been practiced for many years, it is only within the past few decades that serious consideration has been given to using sewage effluents for this purpose. As yet, little progress has been made beyond the investigational stage. In investigations for new sources of ground water, seismic exploration, as used in the establishment of dam sites, has provided a new tool for obtaining underground data.

Transmission Mains

The early gravity aqueducts or transmission mains of large diameter were commonly made of brick or plain concrete, as in the New York and Boston supplies. A few large pressure mains were of riveted steel, as in Newark, whose 48-in. main was the first large steel main in the East. In the West, redwood-stave pressure pipe was popular for years, and although a few wood-stave pipes were installed in

the East they are now generally abandoned. (A section of a typical wood-stave pipe is shown in Fig. 2.) With the development of reinforced-concrete pipe, large-diameter pressure pipe of this type has almost completely replaced the gravity aqueduct of plain concrete.

Pumping

It is in methods of pumping that the greatest change in practice has occurred in the past 75 years. Until about 1900, pumps were of the steam-driven plunger type. Henry R. Worthington had invented the duplex direct-acting pump by 1863. About the same time, the Holly quadruplex crank-and-flywheel pump was developed. Later the Simpson compound engine, originated in England, was introduced into the United States. Still later, the Simpson engine was combined with the Worthington pump, and the Holly-Gaskill type was designed to improve the economy of the original Holly pump. In 1886 the Reynolds triple-expansion pump was designed for and installed at Milwaukee.

Most pumps were designed by their builders and were highly competitive. Perhaps the first pump to be built from plans and specifications prepared by a consulting engineer was a vertical triple-expansion crank-and-flywheel pump designed by E. D. Leavitt and used at the Chestnut Hill pumping station of the Boston water works. The efficiency of these early steam pumps has never been exceeded and as examples of mechanical achievement they are a joy to behold. Several of these old pumping engines are in operation today.

Coincident with improvements in the pumps were improvements in boiler

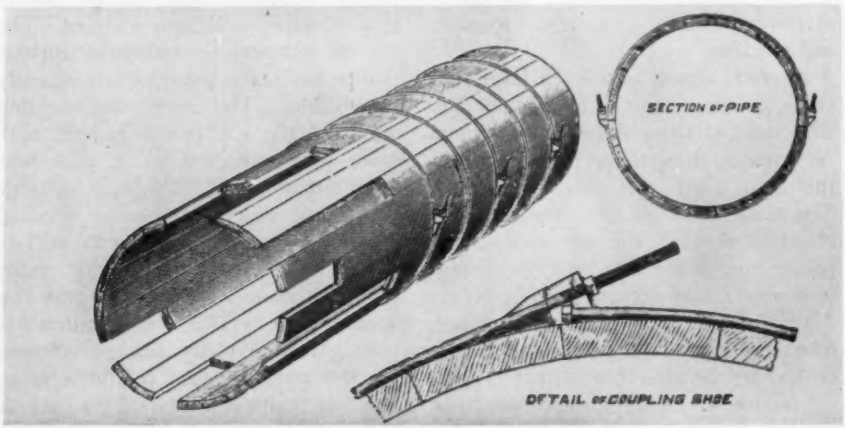

Fig. 2. Continuous Wood-Stave Pipe

Pipe such as that above, usually constructed of California redwood or fir and assembled in the trench, was popular for many years, particularly in the Pacific Northwest, where a number of installations are still in service. Figure from Wegmann (5).

design and the generation of steam at increasing pressures, thus making for better overall station efficiency. Increased pressures were accompanied by the development of the high-speed turbine and the centrifugal pump driven through reduction gears.

About the earliest reference to centrifugal pumps for water works service occurs in a brief item in the old *Engineering News* of September 1891 (*6*) referring to a proposal by W. H. Booth to increase the efficiency of centrifugal pumps, then used for low heads only, by operating them in series. Evidently this suggestion led to the development of the multistage centrifugal pump. At that time Booth stated that the compound centrifugal had never, to his knowledge, been tried.

Early in the 1900's, the centrifugal pump began to come into favor. Two more or less chance coincidences may account for this trend: the development of the steam turbine, and the rise of electric power–generating and transmission systems, with the accompanying increased use of electric motors. (Figure 3 shows both the older triple-expansion pump and a centrifugal pump at the St. Louis, Mo., water works.)

For pumping installations of small and medium size, the internal-combustion engine, either gasoline or diesel, has proved effective, both as a standby unit and as a primary source of power. Such engines were first introduced about 1895, although references to internal-combustion engines will be found at earlier dates in engineering publications.

To a limited extent, water power has been used to operate pumps, and in the past windmills have driven small pumps. In recent years there has been a marked trend to design automatic or semiautomatic pumping stations by the installation of instruments and control equipment, the currently fashionable name for this development being "automation."

Distribution

Early distribution systems were laid out with comparatively little thought about the capacities required to provide sufficient volume for peak demands, and with very little eye to future expansion. It is likely that most of the early systems were constructed of pipe which was much too small. This seems to have been particularly true of those systems built by private promoters. John R. Freeman was one of the first engineers to demonstrate the quantity of water required for fire streams and the necessity for mains of adequate size to provide that quantity. (A typical early hydrant is shown in Fig. 4.) At a meeting of NEWWA in 1889, Freeman asserted that "any man who laid a 4-in. main near a factory ought to be hanged" (*7*).

Today data concerning water requirements are far more complete than they were years ago, and methods such as electronic network analyzers are available for the design of distribution pipe grids. Future needs are anticipated and planned for, although, unfortunately, funds for expansions and extensions are seldom forthcoming until the well runs dry or nearly dry.

Pipes used in the early distribution systems were either cast iron or so-called "cement pipe." This cement pipe, of which many miles were in service at one time, consisted of a central core of thin sheet iron surrounded inside and out by cement mortar. The joints were of cement. The reports of experience with this type of pipe were many and varied. For low pressures

and with good workmanship they served their purpose quite well, and were economical to make and lay. As pressures increased and the size of pipes became larger, however, leakage and breakage brought about a loss in popularity and today most of the type has been replaced.

the most widely employed type of pipe. One of its limitations is susceptibility to tuberculation. This has led to the development of protective coatings of various types. Lining with cement mortar came into vogue over 30 years ago. A technique of cleaning and cement-lining small-diameter pipes in

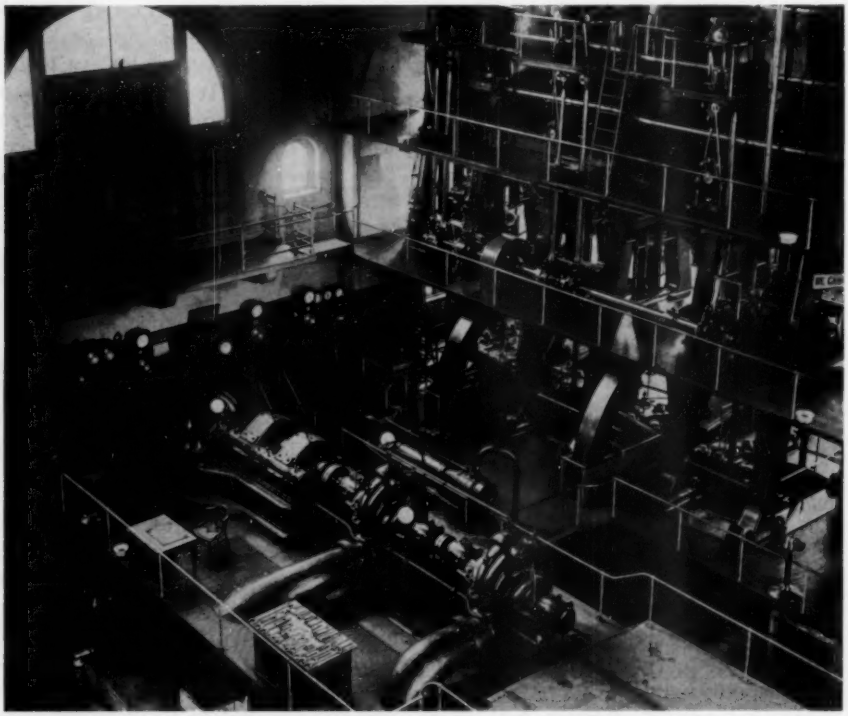

Fig. 3. Triple-Expansion and Centrifugal Pumps, St. Louis

The old type triple-expansion pump, seen in background, provides an interesting contrast to the relatively modern centrifugal pump in the foreground. Photo courtesy of Water Div., Dept. of Public Utilities, St. Louis, Mo.

About 30 years ago asbestos-cement pipe was introduced into this country. Since then many miles of this type of pipe have been installed.

Cast-iron pipe, first used in Philadelphia about 150 years ago, has been

place was introduced into this country in 1939 at Charleston, S.C., and Falmouth, Mass. Other methods have been used for large-diameter pipe.

Originally, cast-iron pipe was pit cast, but in the early 1920's centrifu-

gally cast pipe began to be employed, and at present is the most common pipe used. Fittings, of necessity, are still cast substantially as in the past.

At the time Fanning's treatise was written, there were no uniform standards for cast-iron pipe. Different cities had different requirements as to thickness of barrel and design of bell-and-spigot ends. The first standard for cast-iron pipe promulgated by any association was an unofficial AWWA standard in 1890. In 1902, NEWWA adopted a set of uniform specifications for pit-cast pipe and in 1908 AWWA offered the specifications which, since modified from time to time, are now in general use.

The use of lead joints for bell-and-spigot pipe has been rather common practice over the years. It has been supplanted in part, however, by the use of sulfur compound joints and, more recently, of various types of joints involving rubber gaskets. From the earliest days of AWWA's existence the matter of specifications for water works materials and equipment has been the subject of numerous papers, committee reports, and in-meeting discussions. A review of the activities of AWWA and its members in these matters could well be made the subject of another historical paper. A glance at the index of the JOURNAL is sufficient to demonstrate this fact.

The result of these activities has been the establishment of standards and tentative standards for many items, in addition to pipe, which go into water works systems. This accomplishment alone may well be considered sufficient justification for the existence of AWWA.

The need for local storage facilities early led to the construction of small reservoirs on elevated ground and of steel or wrought-iron standpipes. About 50 years ago numerous standpipes of reinforced concrete were also erected, although few have been installed in recent years. The use of prestressed concrete, however, is developing further interest in this type of construction at the present time. Some of the early standpipes, because of faulty design or construction, collapsed. Eventually, the correction of these errors resulted in good design and construction. The plates of early steel standpipes were riveted, but present practice is to use welded steel increasingly. Protective coatings to prevent corrosion of the interior of standpipes have long been used, and in recent years cathodic protection has been widely developed and applied. (An early standpipe, Chicago's famous "old water tower" is shown in Fig. 5.)

Elevated tanks on towers have been used for many years, particularly in flat areas. Today, however, tanks of relatively shallow depths and large diameters, with ellipsoidal bottoms, are frequently installed to utilize the maximum storage capacity at the optimum elevation. In 1891, an elevated tank with hemispherical bottom was designed by Johnson & Flad, consulting engineers of St. Louis, Mo.

As long ago as 1889 the practice of covering distributing reservoirs was being advocated to prevent pollution and to control algal growth although, in general, such reservoirs were uncovered.

At the first convention of the AWWA in St. Louis in 1881, the relative merits of service pipe materials was discussed at some length. In 1884 W. H. Richards, superintendent of the water works at New London, Conn., declared that "probably in no other particular in the designing of systems

of water supply have so many errors been made as in fixing the size and selecting the material for service pipe." Until then the only materials extensively used were lead, tin-lined lead, and wrought iron, with or without some coating or lining. Today, lead is seldom used, but galvanized wrought iron with or without cement lining, probably ranks first in current practice, although copper has also become popular. Investigations have been made, and are still in progress, into the use of pipe of plastic materials, and a few installations have been made.

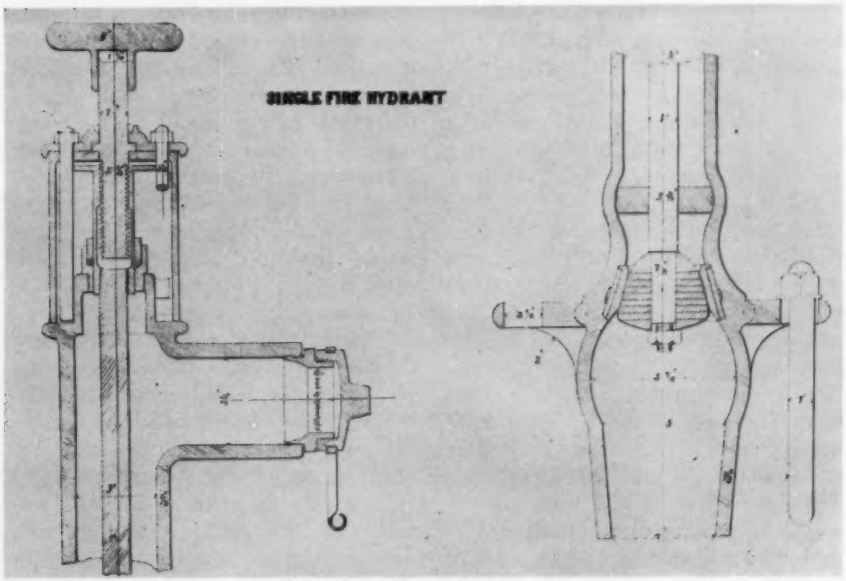

Fig. 4. Fire Hydrant Used in Brooklyn Water Works, 1865

Section shown is taken from Plate 48 of the Kirkwood report on the Brooklyn, N.Y., water supply system (8).

Meters

In the field of metering, the invention of the venturi meter by Clemens Herschel, described by him in a paper presented before ASCE in 1887 (*10*), marks an important milestone in the art of water supply engineering. According to M. N. Baker, the first practical installation of a venturi meter was in the Newark, N.J., water supply in 1892 (*11*). For installation on large mains this type of meter remains standard, although the propeller and orifice-plate types have been developed for use with mains of small and medium size.

The matter of household meters has probably been the topic of more discussion, controversy, and papers than almost any other subject in the water works field. Again referring to the 1881 convention of AWWA it is found

to be the scene of a discussion on metering. Although the water works engineer of today is an advocate of universal metering of services, there remain many municipalities in which this is not practiced.

Summary

The basic principles of water works engineering have remained substantially the same over the past 75 years. Naturally there has accumulated a vast amount of data and experience. Furthermore, new materials have become available and new equipment has been developed.

The hydrological records and the topographic maps prepared by the USGS now constitute an important part of the data not available to the designing engineer three-quarters of a century ago.

Increased knowledge of foundation requirements and concrete production and behavior, together with vastly improved production equipment and methods have resulted in masonry dams of far greater magnitude than would have been attempted in 1881. The formulation of the theories of soil mechanics has markedly affected the design and construction of earth dams.

The availability of sources of ground water has increased greatly as a result of the development of the large-bore gravel-packed well and the submerged turbine-type pump.

Large transmission mains, from source to distribution system, are now commonly pressure conduits of reinforced concrete. Earlier practice was to use gravity aqueducts of brick or plain concrete and to some extent, steel or wood-stave pipe.

Distribution systems are now designed with more ample capacity.

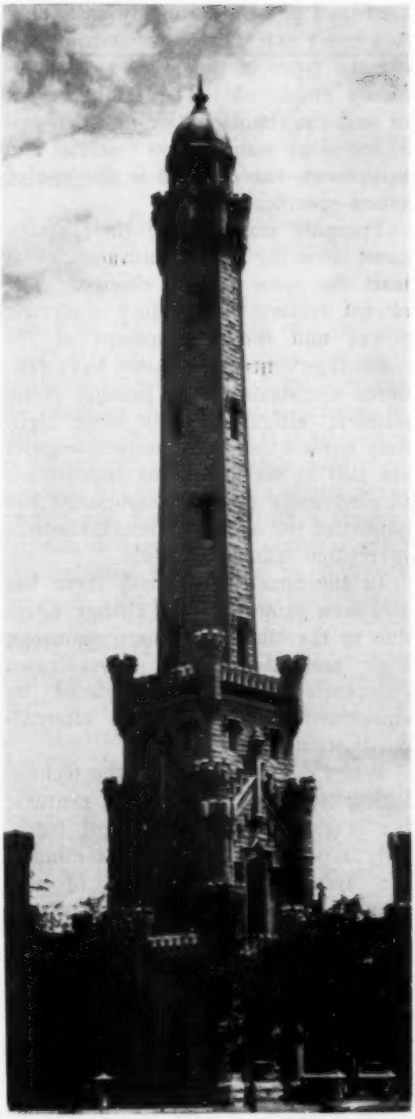

Fig. 5. "Old Water Tower," Chicago

Built in 1869 to house an "unsightly" steel standpipe 138 ft high, the octagonal stone tower, 154 ft high, is a survivor of the Great Fire.

Cast-iron pipe centrifugally cast, and, to a lesser extent, asbestos-cement pipe are the types of pipe now most commonly employed. The establishment of uniform standards for pipe, as well as for other water works material and equipment, has resulted in the use of sound specifications.

Pumping stations and their equipment show the greatest advance, or at least the most radical change. The almost universal availability of electric power and the development of the multistage centrifugal pump have rendered the steam-driven plunger pump obsolete, although a few large high-duty triple-expansion pumping engines are still in service. This substitution of electrically operated equipment has permitted the use of automatic controls to replace manual controls.

In the construction field there has also been another radical change, again due to the change in energy sources. Pick and shovel and horse-drawn dumpcarts have been replaced by equipment powered with internal-combustion engines.

When one contemplates the technological advances of the past century, the single feature which most forcefully impresses itself upon the mind is the tremendous influence of the changes in energy sources. Direct utilization of steam power has given way largely to electrical transmission of energy. Human and animal power have been replaced by the internal-combustion engine. This philosophic observation is equally applicable to the water works field. But what of the future? We now appear to be on the verge of another change, even more drastic, in the harnessing of potential power in the form of nuclear energy. What this will mean 75 years hence, no man can say. That it will have radical effects upon water works practice, no man can deny.

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75 Years of Too Cheap Water

John H. Murdoch Jr.

A paper presented on May 10, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by John H. Murdoch Jr., Counsel, American Water Works Service Co., Philadelphia, Pa.

ON the occasion of the 75th anniversary of the American Water Works Association it would be considered appropriate that papers presented be devoted to accounts of the great progress made in water works practice during the life of AWWA and under its influence. Such papers have indeed been presented—and they have been well prepared, and are of great value. This paper, however, has a different purpose. It is written to call attention to certain failures in water works practice and to consider some of the reasons for those failures.

It should be clearly understood that all that is here written has application to both publicly and privately owned enterprises. The failures of which this paper treats can be traced to water works men, not to regulatory bodies or municipal authorities. It is true, of course, that such bodies may be partly to blame; nevertheless, the primary cause of failure has been in water works men themselves, as individuals. "The fault, dear Brutus, is not in our stars but in ourselves, that we are underlings."

Water works systems have always failed, and continue to fail today, to offer to the public or to their customers the water service desired. Instead of providing the service demanded, water works men excuse their failure as the result of poverty—yet they are publicly proud of the low prices charged for water service. The consumer has been educated by water works management to consider water cheap—"cheap as dirt"—and the result of that education is an instinctive, passionate public resistance to every move to secure sufficient funds for fully adequate service. Service deficiencies will continue until the industry represented by AWWA becomes ashamed of too cheap water.

Early History

Prior to 1880 (one year before the birth of AWWA) there were only 598 public water works systems in the United States, which included, at that time, 929 cities and towns with a population of 2,500 or greater. The decade 1870–1880 was the first in which the increase in the number of water works exceeded the increase in the number of cities and towns. After 1880 many more public water supply systems were established, but it was not until after 1900 that most of these systems were accepted by the general public as sources of potable water.

A water system was put into service in Washington, Pa., in 1887, which derived its supply from a small creek with off-stream impoundment. There was no filter system until 1900; the water delivered was often turbid, until the filters were placed in service; there were periodic—indeed, frequent—inter-

ruptions of service because of lack of supply. There are no available statistics on the number of customers for some of the early years, but in 1897, after 10 years of service, there were only 460 service taps in a territory with a population of about 14,000—or a ratio of 1 to 30 persons. By 1910 the population of the territory was 20,000, and the customers attached totaled about 3,000—a ratio of roughly 1:6.6. In 1954, there were 18,000 customers served in a territory with a population of about 69,000—or a ratio of 1:3.9. Particular attention is called to the improvement in the ratio of customers to population in the period between 1897 and 1910—from 1:30 to 1:6.6. New supplies were developed in 1900 and in the same year the filter plant was installed.

At Butler, Pa., in 1897, after 20 years of service, the water system had only 500 service taps for a population in excess of 9,000, or a ratio of 1:18. Surface water from streams was the sole source of supply and no filters were installed until 1902. The customer-to-population ratio in 1954 was 1:4.

Monongahela City, Pa., in 1897, after 9 years of service had only 149 customers and a ratio of about 1:20. The supply source was the Monongahela River, unfiltered until after 1900. In 1954 the ratio was 1:3.8.

These systems were typical of their times. High turbidity in the delivered water prior to the installation of filters; a very high ratio of population to customers in the early history, and improved ratios after improvements in service; these characteristics were the rule, and not the exception.

Why were water works so rare in the early days, and why were customers so slow to connect? The truth seems to be that people saw little need for public supplies, particularly for domestic use. The service offered did not appear to be as good as people could get from wells and cisterns.

It was not until after 1875 that scientists knew for certain that waterborne germs could carry disease into the human body, and it was after 1900 before the general public realized the danger of using impure water. In the early days, water was good and pure if it appeared clean—sparkling, clear, cool, and free from objectionable odor. Such water was readily available to most homes and business places from the backyard well. People went out day after day, winter and summer, pumping water from their own wells and carrying it in buckets into the house. They liked the water. It was clear and cold and fresh tasting. They never knew that the dysentery, "summer complaint," or typhoid which attacked them in epidemics or were endemic could be traced to their own "good water."

Others depended on cisterns, which were satisfactory in many ways. The water could be pumped into the homes and even into tanks from which it could flow by gravity into that rare luxury, the family bathroom. True, the cisterns often went dry in summer, and they were often far from clean—but they were convenient.

Except in the homes of the wealthy, who had bathrooms and cesspools, domestic sanitary arrangements were based upon the ever present backyard outhouse, not too far distant from the back door—or from the well. The system was considered normal and was thought to involve no elements of hardship or danger.

Until after 1900, when filtration of public water supplies began to be fairly common, the public systems in general

were no safer than the backyard well supplies. It was common practice to take water from creeks and rivers, with at most the straining effect of an intake. Typhoid was so prevalent as to be commonplace. The law books reveal case after case of typhoid and related diseases being traced to public water supplies.

In E. M. Baker's introduction to the *Manual of American Water Works* (*1*), there appear some paragraphs which reveal how late in history it was that the public and public water supply officials became interested in pure water. The quotations which follow not only demonstrate the increased interest in purification during the period from 1892 to 1897, but also indicate that filtration was not generally in practice even at the later date. Is it any wonder that many people still used their own wells and cisterns? In the following quotation from Baker, the italics are those of the present author:

> Five years have seen a wonderful increase in the popular demand for pure water. This has been secured in many instances by providing entirely new and naturally satisfactory sources of supply, and in others by some method of water purification. Mechanical filters were introduced some 12 or 15 years ago, and slow sand filtration has been in use at a few places in this country for many years. But within the past 5–7 years each process has been coming rapidly to the front, until in the present *Manual* over 100 mechanical filtration plants are listed, and perhaps ten or twelve filter bed systems operated in accordance with the recent flood of light on the subject. Slow sand filtration has been gradually gaining in favor, as the result of disinterested scientific investigation. Mechanical filters have been adopted at scores of places to remove such manifest impurities as silt, color, vegetable matter, odor, and iron, aeration commonly supplementing filtration where odor or iron are to be removed. Such impurities as these appeal so powerfully to the senses that the people rise up in veritable wrath and demand their removal. *Equally strong insistence on the removal of unseen, but infinitely more dangerous, organic impurities comes more slowly, but is making itself felt none the less surely in many communities.* Chemistry, bacteriology, and good common sense are aiding mightily in placing impure water supplies in their true light before the public, and in indicating how their use may be rendered unnecessary.
>
> While much is claimed for the bacterial efficiency of mechanical filters, the fact remains that the claims are not yet so firmly verified by scientific research as are those of slow sand filtration. The elaborate experiments at Providence tend to greatly increase confidence in the bacterial efficiency of the process, and all interested in the subject are eagerly awaiting the results of the yet more exhaustive Louisville experiments, on a water of an altogether different character, carried on with a variety of makes of filters, all sufficiently large to make them, in point of size, comparable with filters in regular use. There is no doubt but what both mechanical and slow sand filtration have a great future in this country, and that with the aid of one or the other, *pure water for all is a possibility*.
>
> There are indications that sedimentation will come into still more general use for waters carrying silt. Large settling basins have been built within a few years at St. Louis and Omaha, and some have long been in use elsewhere. *Filter beds for St. Louis were recommended 30 years ago by the late James Kirkwood,* in an elaborate report, which, for a quarter of a century, was about the only available treatise in English on the subject of filtration. *Mr. Kirkwood considered settling basins an essential accompaniment of filtration, and they were built, although the filters were not.*
>
> Larger settling basins have been constructed since, in connection with the

new source of supply, higher up the Mississippi River, and the *addition of filters is now under consideration.* Besides Providence, Louisville, and St. Louis, at each of which places *filters will doubtless be installed within a few years, Cincinnati and Minneapolis are practically committed to filtration, and Philadelphia, Pittsburg[h] and Albany may soon follow. Other cities, great and small, are also rapidly coming into line, so that in 10 years we may expect to see pure water and low typhoid death rates in many places where the contrary now prevails.*

From a careful scanning of local newspaper files prior to the times that water works systems were established in the various communities, it appears that there were two public needs which both editors and correspondent readers felt could best be met through the medium of public water supply agencies. One was the need of water for fire-fighting, the other the need of water with which the summer dust on the streets could be kept under control. There was a recognition that a better system for making water available for fighting fires was highly desirable to displace or supplement the bucket-passing brigades taking water from nearby wells, private cisterns, or the public fire cisterns located in the high-value central business area. The newspapers played up this need and the editors and their subscribers wished to have water available for keeping down the clouds of dust that were the summer scourge of all small cities and towns. Once in a long while, a newspaper mentioned the desirability of having pure water piped into the homes so that baths could be taken easily in private. The mention of water for domestic use was so rare that it can be understood only to mean that people were not very interested. A few civic leaders were usually active in getting water for the two recognized needs—firefighting and the laying of dust—but they had a difficult time in persuading enough people to join them in getting the system created, and a still more difficult time in persuading enough people to become customers to make the system self-sustaining. In fact, many systems failed and were reorganized because of a lack of the necessary number of customers required to reach the break-even point. Backyard wells and private cisterns were so well known and were so satisfactory to the people that a selling effort of major proportions was required to persuade them to spend any money for a service of doubtful advantage.

Indeed, in those early days the advantages to domestic customers were doubtful. The public supply was often poorly engineered and the supplies were frequently found to be inadequate. Curtailed or completely discontinued service was far from rare. The quality of the water supply was often poor: turbidity was common, and filters unknown (and even after they became well developed were only reluctantly adopted). Under these circumstances it is easy to see that only convenience plus low price would induce the domestic customer to become one of the patrons required to keep the new system alive. Low water service rates plus the convenience of interior plumbing overcame the competition of the wells and cisterns as sources of supply for washing and sanitation. For cooking and for drinking, private sources were not given up until the germ theory of disease became publicly accepted and until the public supplies became dependable from the health standpoint. Then and then only did public supplies grow in importance and in the public estimation.

Thus, in the early days—prior to 1881 and on into the 1890's and early

1900's—public water supplies could be created and kept alive only by offering economic competition to the wells and cisterns, which were generally more highly regarded. Water works men have never gotten over it. In their minds and in the minds of the public, water is considered cheap—cheap enough in those beginning days to induce people to put it into their homes as a sanitary convenience—never as healthful and pleasant for human consumption. Our water works founders, in order to secure the number of customers required to make the enterprise possible, kept the cost of their plants to the bare minimum and fixed their customers' service charges so low as to be attractive to people who really did not much want the rather inferior service being offered. Understandably, the public came to look on water as cheap, even after engineers and bacteriologists learned how to improve quality; and today the industry encourages them to continue in this attitude. Operators have been so imbued with the inherited idea that water is and must be cheap that they advertise, or boast, that water is cheap as dirt and thus build up in the minds of customers an instinctive, passionate resistance to any effort to bring into water departments adequate revenues for adequate service. Water works continue to give less than adequate service and plead poverty as the reason for the failures. Poverty *is* the reason, but the poverty is caused by inexcusable pride in too cheap water.

Current Attitudes

All have been trained in the art of demonstrating that water is cheap. Any good water works manager can show that we process and deliver water under pressure directly into the homes of our customers and directly to the water-using facilities, in large or small quantities as the customer wishes, from moment to moment, and do it for a charge below the normal cigarette bill of the family. Our ton-mile charges for transportation are below those of the railroads. We furnish the most essential of the public services and we do it at a cost far below the costs of the less essential. We can prove that water is cheap. In fact, it is too cheap.

Water works are not giving fully adequate service because they cannot afford to give such fully adequate service. Poverty is the excuse—the reason is the habit of too cheap water.

We claim that we deliver water to our customers as they need it. The claim is not well founded. Water is delivered when it is available in source and when the pumps and distribution systems are not overloaded. When the customers want it most they cannot get it—poverty, caused by too cheap water. We are too poor to make adequate provision in our sources of supply to carry our demands through the recent recurrence of droughts. We are too poor to develop the supply facilities which will be needed to meet increasing demands in the near future, although we know that long years of effort must go into such developments. The developments should have been started 5 or 10 years ago, but could not be undertaken because of—poverty, caused by too cheap water.

There are bottlenecks in our treatment plants and pumping stations and there are inadequate provisions for standby emergency facilities because we must be so very careful to conserve funds. We must face the likelihood of shutdowns or of curtailed service because we cannot afford to make our plants fully adequate to meet emergencies or peak loads.

Our distribution systems need to be strengthened and brought up to the capacity required to give fully adequate service under present and anticipated customer demands. We need reinforcing mains to get the water away from our expanded pumping stations. We must extend our system of arterial mains as populations move into new areas and as industry changes locations, thereby bringing about changes in the geographic distribution of water demands. We delay and often resist demands for such strengthening because we are too poor to keep abreast of demands, to say nothing of anticipating them. We are forced by poverty—always—into the role of stumps in the highway of progress.

Distribution systems are not now capable of rendering adequate service to our existing customers. Because we cannot afford either an adequate system of mains or adequate distribution system storage, we take the position that it is not our function to supply water to our customers in the quantities they want and under the pressures they want at the times they want it.

We need more engineers, bacteriologists, chemists and trained managers; but we fail to get them because we cannot afford to pay the going rates established by industries whose income is governed by competition rather than by tradition—as is ours.

So we carefully explain to the customers and to the public that the type of service which is wanted and which we know how to render, cannot be rendered because we cannot afford it.

The Remedy

Let each man remember that public water supply systems are no longer in competition with backyard wells and cisterns and need not cut service or charges in order to get essential business. Let each remember that the public now considers his service essential and wants that service improved, strengthened, and extended. Then let the water works man, having cleared his mind of the old habits of thought based on long-forgotten conditions, begin the process of leading the people to a realization that adequate service such as they want, *can* and *will* be given whenever they want to pay the new costs rather than traditional rates.

We now have cheap water—water *too* cheap for adequate service. We must stop being proud of cheap water and begin to be ashamed of too cheap water.

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The Nation's Water Resources

Fred G. Aandahl

An address delivered on May 8, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Fred G. Aandahl, Asst. Secy., US Dept. of the Interior, Washington, D.C.

IT is a pleasure for me to appear before the American Water Works Association. Anyone who has spent a good part of his life in the Dakotas cannot help but be conscious of water. Throughout the growing season men constantly scan the horizon for rain clouds which will mean the difference between a bountiful crop and a poor one. On the plains you do not look up to see if it is going to rain: the storms come at you sideways. In that area nature is capricious, and precipitation falls in an erratic pattern. Often it will rain all around you and leave you high and dry. Under these conditions one cannot help but be impressed by the importance of water.

In my home state the people have learned through sad experience that they have to conserve water. As you fly over North Dakota and other western states you will see many fields that are alternately light and dark colored. Half the area is planted and the other half is left fallow in order to conserve moisture. Two years' accumulation of rainfall is used to produce one crop. Most of the precipitation in that area originates from the Gulf of Mexico, and by the time that tropical air has reached North Dakota it is pretty dry. Stabilization of agriculture and the growth of cities and industries will be dependent on new sources of water supply made possible by the Missouri Basin Project.

The West has never been complacent about water, but in many other parts of the country the water supply is often taken for granted. This can be taken as a tribute to the fine job you men have done. Most cities have been able to provide water in such abundance and so cheaply that people are able to water their lawns, wash their cars, or even simply waste it without thinking twice about it. Although there is considerable variation from place to place, the average price per 1,000 gal is 30 cents. I can think of no greater bargain to be had.

The entire nation became aware of the water problem in 1950, when New York City was threatened with a severe water shortage. Severe penalties were imposed for unauthorized use, and men were asked to go without shaving on certain days to dramatize the situation. The New York shortage was perhaps a fortunate warning. It shocked many people, and made them aware of a dangerous situation.

The USGS report, *Public Water Shortages, 1953*, showed that the problem of shortages was not limited to any particular area. Only Idaho, Mississippi, and Rhode Island reported no shortages. The study pointed out that one out of four persons served by pub-

lic water supply systems had his use of water curtailed some time during that year. Toward the end of 1954 the *New York Times* reported widespread water shortages in the deep South. It noted that thousands of people in rural and urban areas throughout Alabama, Georgia, and South Carolina were living with acute water shortages. At a western area development conference sponsored by the Stanford Research Institute and other regional associations it was correctly stated that water supply would be a limiting factor in the expansion of new industry in the area. Other stories of water shortages make the news almost every day. It appears that this problem is going to be with us from now on.

Increasing Requirements

A number of factors are responsible for water shortages, including population growth, air conditioning, industrial growth, new technology, and increased requirements for agricultural purposes. On the basis of conservative estimates, requirements for all these purposes will increase rapidly and the situation is likely to get progressively worse. Will the corrective actions now being taken provide adequate water supplies for the future? Members of the water works profession are better able to answer that question than I.

There are four major categories of water use: [1] public water supply (including domestic, commercial, and industrial use); [2] self-supplied industrial use; [3] steam-produced electric power; and [4] irrigation. These account for 98 per cent of the total water use.

The population of the United States grew at a fairly steady pace during the first half of this century. World War II marks the starting point of a population explosion in this country. By 1975 we shall have passed the 200,000,000 mark. Approximately three-fourths of our people will be served by public water supplies. This growth in absolute numbers, coupled with increased per capita requirements, will increase the daily demand from the present 17 bil gal to a projected 30 bil gal by 1975. We recognize, of course, that about 90 per cent is nonconsumptive use which, except in the coastal cities, is returned for reuse. In order to expand public water supplies to accommodate this 20-year load growth, however, a capital outlay of about eight billion dollars will be required.

Our growing population is the key to our rapidly expanding economy. Adequate water supply will become an increasingly important factor in the location of industry. At present 60 bil gal a day is utilized in industrial processes. Not only is industry expanding, but new industrial processes—such as those used in the manufacture of synthetic fibers, synthetic rubber, and petrochemicals—require tremendous volumes of water. By 1975 industrial water requirements will have doubled. Again, it is estimated that 10 per cent or less will be used consumptively.

Electricity will be the motive force behind our industrial growth, and domestic consumption will continue to rise. Steam power plants utilize 60 bil gal a day at present. By 1975 this requirement also will have more than doubled. In this use, there is practically no net loss of water, since most of it is employed for cooling.

The other major use of water is irrigation. The present average daily consumption of 120 bil gal is double the amount used in any other category.

By 1975 irrigation will still retain first position with an average daily demand of 170 bil gal. Through evaporation and transpiration a considerable amount of water is returned to the atmosphere. An undetermined amount percolates through the soil and replenishes ground water supplies. Usable return flows amount to 20–60 per cent.

When the requirements of these four major categories are added together, the total current daily demand is found to be slightly more than 250 bil gal. By 1975 the total daily requirements for all categories will amount to approximately 450 bil gal. Thus, our requirements will be nearly double what they are today. These, it should be remembered, are conservative estimates.

Meeting New Demands

The water supply problem has two aspects. Our people and industries will require a much larger volume of water, which will have to meet certain standards of quality. Domestic supplies must obviously be of the highest purity. Industrial water must often measure up to specific standards of clarity, softness, and temperature. The question before us, then, is whether or not we will able to meet this demand. The answer is, that, with adequate planning, the overall requirements can be met. The nation as a whole has a supply potential considerably greater than the foreseeable demand. On the other hand, there will continue to be local problem areas which can only be adequately supplied at great cost. As a general rule, water supply problems will have to be worked out on a local watershed basis.

Only one-fourth of the precipitation which falls reaches the sea in the form of runoff. In arid regions runoff may be nonexistent or very flashy, while in humid areas some heavy seasonal flood flows are experienced. Where the land retains water effectively, and man has worked with nature, the discharge is somewhat equalized throughout the year. Although total runoff is about five times the demand at present, problems arise because it is so erratic. There is no real total water shortage, but we have not yet learned how to use the resources at our disposal. Most of our population is located in areas endowed with a fairly dependable water supply. Man is learning that if he chooses to invade the dry regions he must "pay the piper."

As a whole, the water supply picture is good. Nevertheless, because the supply is so variable in time, place, and quality, there will be many local supply problems. In planning our system these variables must be taken into account if all needs are to be met. Even regions that receive adequate annual precipitation experience seasonal droughts, and systems must be designed to meet the demand during dry periods. There are a number of engineering projects which will transport water from surplus to deficit areas for agricultural and municipal use. Among these the Central Valley project in California is an outstanding example. The problem of water quality will become increasingly important, for our water supply will be put through more cycles of reuse as our population grows and our economy expands. New supplies will continually have to be developed, but the immediate major problem is one of providing the pumping, treating, and transmission facilities needed to utilize water from sources presently available.

There are many alternatives by which we can assure adequate future

water supplies: water losses may be reduced; present supplies may be developed further; water can be used more efficiently; and new sources of supply must be developed.

Federal Activity

I would like to talk about some of the research the federal government is doing on problems of water supply. Some of the important work the various federal agencies do is unspectacular and does not receive much publicity. Other projects catch the imagination and are well publicized. The investigations I have in mind fall into both categories.

I would like to place basic data activities first on the list in order to emphasize their importance. There can be no rational planning for our future water supplies without adequate knowledge concerning the growing demand for water. At the same time, additional information about potential sources of supply is required. The Department of the Interior, the Department of Commerce, and the Department of Health, Education, and Welfare are all engaged in making basic data studies. Facts are needed —facts concerning regional and local water supply, involving all the variables of stream discharge, storage and movement of ground water, mineral concentration, and similar matters. Detailed data for each area must then be related to dependable data on water supply needs as determined by population growth and movement. The task of collecting and analyzing basic data is both time-consuming and costly, but to proceed without this information can be far more costly—if not, indeed, tragic.

The problem of phreatophyte control has been the object of continuing interagency study, especially in the Southwest. Water-loving plants, such as willow, cottonwood, and saltcedar, have little economic value and consume enormous quantities of water. Estimates of the amount of water transpired by phreatophytes in the western states vary in the range of 15,000,000–25,000,000 acre-ft of water annually. This is greater than the average annual flow of the Colorado River at Lee Ferry (14,400,000 acre-ft). Of course not all of this water is salvageable. In Nevada, for example, it is estimated that only 25 per cent of the 1,500,000 acre-ft consumed by phreatophytes might economically be saved for beneficial use. Potential increases of this size, however, are of considerable importance in the West.

A number of interesting experiments are being conducted by the Forest Service of the Department of Agriculture to determine the effect of various forest management practices on snow retention and runoff. By thinning young stands, and by varying the cutting pattern on mature stands, snow pack has been increased, with a subsequent increase in volume of runoff. A careful balance must be determined for each type of area if optimum production of water is to be obtained. Experiments have shown that the amount of water evaporated from snow in an open meadow is twice the amount lost from semiopen pine and three times the amount lost from a small opening in a fir forest. In addition to increasing the volume of runoff, forest management practices can affect the time of runoff by retarding the snow melt. Much research must be completed and evaluated before there can be any practical application of these techniques. The knowledge thus gained, however, becomes increasingly

important as the water problems become more acute.

Artificial-Recharge Studies

Ground water will also become an increasingly important source of supply in the future. Our lack of knowledge about ground water has in some areas prevented full use of this resource, while in certain other places it has led to abuse. In a number of areas in the Southwest, water is being mined at a rate considerably greater than the rate of natural recharge. On the High Plains of Texas the ground water level has dropped almost 2 ft a year over the last 20 years. In the San Joaquin Valley, in California, the water table has dropped 150 ft in some areas and 300 ft in others since extensive irrigation started. Most of the decline has taken place in the last 15 years. Continuation of such practices can only lead to disaster. As the total volume of water stored in the ground is several times greater than the available surface supply at any one time, it is essential that we learn more about it.

The USGS is conducting research aimed at increasing the utility of ground water reservoirs through artificial recharge. This may be accomplished by means of water spreading or by the injection of water into recharge wells. Surface recharge is the more common method and usually involves the construction of seepage pits, or the controlled release of flood water into permeable stream channels or ditches. Recharge through wells must be employed when the land surface is impermeable. This method is more complicated and more expensive than surface recharge, but in some areas it is the only feasible method. The USGS is investigating the possibility of recharging ground waters in the rice-growing region of Arkansas where recharging through wells is the only alternative. It may seem strange that an area which receives 50 in. of rain is depleting its ground water supply. The area is overlayed with relatively impermeable clay and silt deposits, however, so that the natural recharge falls short of the volume pumped.

Weather Modification

I am sure that each of you has read about weather control experiments that have taken place during the last few years. You will receive a detailed report on this subject at another session. I would like to touch on weather modification as it relates to irrigation.

At present there seems little likelihood that artificially induced precipitation can ever substitute for irrigation in arid regions. Precipitation cannot be caused when there is insufficient moisture in the air or when temperature conditions are unfavorable. Thus it may not always be possible to cause rain when it is needed for the crops. Air movements are so erratic that it would be impractical to deposit rainfall on localized plots. Even if it were possible to capture all the moisture in the air, this amount would not be sufficient to support intensive agriculture in arid regions. The principle source of irrigation water is the snow pack in the upper watersheds. Storage reservoirs will still be required to conserve water for use when needed.

Control of evaporation losses from reservoirs has recently been receiving attention. Three weeks ago a conference on reservoir evaporation control was held at San Antonio, Tex. You are all aware that the loss of water from the surface of reservoirs through evaporation is sizeable and variable. In some humid areas the evaporation

loss is very nominal, 2–4 ft annually. But in the drier sections, where water is precious, nature causes losses of up to 8 ft a year. There have been various proposals for reducing evaporation, but none have proved entirely feasible as yet. One method of evaporation control utilizes long chain alcohols in a layer only one molecule thick over the water surface. Pilot plant experiments have shown that under favorable conditions this thin layer of alcohol can reduce evaporation significantly. Additional tests on larger bodies of water are planned. At present it is believed that the use of long-chain alcohols will not adversely affect taste and odor of the water.

Saline-Water Conversion

The Office of Saline Water of the Department of the Interior has been charged with the responsibility of developing economically feasible processes for converting saline water to fresh water. In order to assure that the processes being developed will be capable of producing water of the quality and quantity necessary to meet the requirements of industry, the Department of the Interior is now planning to obtain information on: the present and future needs of industry for converted water; the areas in which saline-water conversion will be needed; the quantity and quality of this water required; and the cost of converting saline water.

I hesitate to quote conversion costs but, as the reduction of costs is a principal objective of the saline water research, we should have some general idea of their past and probable future magnitude. Such costs unfortunately must be based upon numerous assumptions as to life of equipment, interest rates, costs of power, fuel, labor, and equipment, and the like.

Until recently it was necessary to depend upon the best available information from leading authorities for such estimates. Now, however, with the help of several capable engineering organizations, the Department of the Interior has prepared a standard cost-estimating procedure which will soon be applied to existing and future conversion processes. Until that is done it is only possible to draw a few general comparisons, and these must necessarily be based upon the former estimates of leading authorities.

In 1952, before the research program was begun, multiple-effect evaporation was estimated to produce water at about $500–$1,000 per acre-foot. Processes under design by the department today may be able to produce the water at about $200 per acre-foot and, if advantage can be taken of waste heat from condensers of power-generation equipment in a multipurpose steam-generating conversion plant, the cost allocable to water conversion may be as low as $100 per acre-foot.

With vapor-compression distillation, the 1952 costs were estimated variously from about $400 per acre-foot to as high as $1,200. Improvements in vapor-compression cycles being developed under the program give promise of producing water at about $200 per acre-foot, and with further research at possibly half that price.

In 1952, solar distillation was estimated to produce water at about $1,000 per acre-foot. With the improvement of a system now being developed, it appears that solar distillation may be capable of producing water

at about $200. Other processes which appear favorable from the standpoint of cost are those utilizing freezing, critical pressures, osmosis, and the process known as electrodialysis, which may be more adaptable for treatment of brackish water containing about one-tenth as much salt as sea water.

Federal Water Resources Policy

With this background of general information let us look at the water resources policy of this administration which can be summed up in a single word—partnership. I speak of parnership in the broadest possible sense. To me it means that the federal, state, and local participants will cooperate in solving their water resource problems, and in addition it means that each will assume some of the responsibilities as well as the costs of carrying out such programs.

I would like to discuss some of the major features of the report of the Presidential Advisory Committee on Water Resources Policy. The first problem the committee recognized was that our store of basic physical facts was inadequate, or that they were ignored. I have already indicated to you how important I believe this problem to be. The committee took a similar view, and recommended that the basic data program be strengthened. It proposed that within the next 5 years the amount of funds allocated at present be doubled to carry out an expansion of all phases of the basic data program in cooperation with states and local units. It was proposed that a minimum of 5 per cent of the allocated funds be spent on evaluation of data. In addition, the committee urged that funds be appropriated on a uniform scale from year to year.

The committee emphasized that there is no "national" water problem. I believe the previous discussion of available water supplies and current needs bears out this statement. There is instead a variety of water problems unique to each region, state, and locality. As a result, there can be no overall plan for water resource development. Planning must be based on existing and projected conditions in each area. The organizational changes proposed by the committee would lessen bureaucratic control, and provide the local population a greater voice in determining how its resources would be developed.

Coordination Efforts

In the past we have had the Department of the Interior, the US Army Corps of Engineers, and the Department of Agriculture, each with a major interest in a different phase of water resource development, pursuing its own program. Some aspects of the water program, such as municipal and industrial water supplies, were often slighted because they did not fall within the purview of any one agency. Often the right hand did not know what the left hand was doing. Only after many costly mistakes were made was there any attempt to coordinate the programs of the federal agencies. In recent years coordination has made remarkable progress, and additional steps are being taken to permit adequate participation of state and local interests. There is still much to be done. The program outlined in the water policy report would provide the guidelines for the needed action.

The committee strongly believed that a sound water resources development plan required all interested groups to participate in the planning process *from the start*. Consequently, it recommended that regional or river basin committees be established as the need arose. Each committee would have a nonvoting chairman appointed by the President of the United States. The federal agencies having responsibility in the area would be represented on the committee and the governor of each affected state would appoint representatives.

The total number of either federal or state representatives is regarded as immaterial, as conflicts would be solved by cooperation rather than by voting strength. These committees should be the principal media through which planning activities of all participants would be coordinated. These committees would prepare and publish joint comprehensive water resources development plans, which would be revised from time to time as conditions in the various regions and in the nation as a whole changed.

The committee has proposed that an office of coordinator of water resources be established in the executive office of the President. In view of the increasing importance of water resources problems, it is felt that some such avenue of presidential direction is desirable. The coordinator would reconcile the inevitable interagency differences, and would develop and establish uniform procedures for all agencies; he would cooperate with the Bureau of the Budget and the Council of Economic Advisers in the evaluation of departmental requests for appropriations; he would work on the reconciliation of water resources policies with other federal policies, and would prepare long-range programs of water resource developments consistent with other public works programs.

Water resources legislation in the past has often been termed "pork barrel" legislation. This designation has not been without some justification. The committee has proposed that an impartial board of review be established to evaluate the economic and engineering feasibility of projects before submittal to the President. The board would be composed of three persons with competence in engineering and economics, or others with recognized abilities and judgment in the resources field. They would have had no connection with the planning of projects submitted for review, nor would they have been involved in the subsequent construction of projects. Such a board would serve full time and would be able to give due consideration to congressional policy and to criteria established by the coordinator of water resources in the evaluation of projects.

We have all heard the charge of the federal government's failure to comply with state water laws. Some of you may have had direct experiences of your own. Water law is complex, and it does not have the virtue of consistency from place to place. New opinions are being rendered all the time, and under these circumstances conflicts are inevitable. The committee has several proposals designed to clarify the situation.

First of all, it recognizes that in many areas land is worthless without the water rights that go with it. The report states: "The principles which recognize water rights as property rights should be accepted. Determinations as to disposition of water should recognize such rights."

The committee recommends that the federal government collaborate with states in a study to determine the relationships between the establishment of property rights to water and the economic and social development of the nation. Such a study would clarify the rights of the respective parties and is a prerequisite to solving the current dilemma in this field.

In the past the failure of the states to come to an agreement on the apportionment of interstate waters has hindered development. The committee urges that the states solve these problems to their mutual satisfaction by means of interstate compacts. Agreements arrived at in this manner are considered preferable to the imposition of federal legislation.

Most of the western states have adopted a set of rather rigid priorities for the use of water, usually listed in the following order: domestic uses, stock watering, irrigation, manufacturing, and power generation. This pattern has evolved over time in response to local conditions. There are many parts of the country where these priorities come in different patterns.

The committee notes that the eastern states are gradually moving away from the strict riparian doctrine. As the increasing importance of water is recognized, statutes pertaining to water use include phrases such as "productive use," "economic use," and "optimum use." The committee believes that each state can determine how water can be used to best advantage within its borders. It rejects the idea that the federal government can dictate priorities; however, it recommends that there be some flexibility with regard to priority of use in order to adjust to changing conditions.

The committee spent a good deal of time in trying to cut the knot of project evaluation. This is a technical problem, and the federal resource agencies are still working out a final solution. I shall touch on only a few of the committee's recommendations here.

In the past, each agency used a different method to evaluate its projects. Each followed procedures which were designed to show their projects in a favorable light. Under these conditions it was not possible to weigh the costs of federal action against alternative means of achieving the same ends. The committee has proposed that in the future all agencies prepare project evaluations on a uniform basis.

The committee recommends that all costs, including interest and taxes, be included in project evaluations. This is necessary if the relative merits of federal projects are to be compared with those of states or private interests.

In the past the evaluation period on some federal projects has been established at considerably more than 100 years. No doubt many projects will be in operation a long time; nevertheless, the committee felt that in estimating benefits and costs the economic life of a project should not exceed 50 years, plus a 10-year development period where such is considered necessary.

Secondary benefits which result from a water resource project are often very great. While the impact on a particular region is both considerable and obvious, it is also true that equal capital investments in projects of a different nature in other areas would also generate secondary benefits. The federal agencies have in the past used secondary benefits as a principal justification for projects. The committee felt that secondary benefits should be

shown in the project report, but that they should be separate from and not confused with the benefits in the evaluation of benefits and costs.

The procedures for obtaining authorization of projects varies among the several agencies. The Secretary of the Interior may authorize construction of certain projects upon finding that they meet specific criteria. The present administration has eschewed this practice, and the Department of the Interior has for the past three years sought specific legislation for each project. The Department of Agriculture, under the Watershed Acts, can authorize its own projects, subject to congressional veto. At the other extreme the US Army Corps of Engineers must have congressional authorization before it can even investigate a project. The water policy committee recommends that all agencies seek congressional authorization prior to construction of projects, and that the procedures be uniform for all.

Cost Responsibilities

The last of the committee's recommendations deals with participation in costs. If there is to be a genuine partnership in the water resources development, the state and local interests should be expected to assume a fair share of the costs along with their increased responsibilities. A major share of the project benefits accrue to particular individuals and to particular areas. The committee has recommended that the share of the costs to be borne by the beneficiaries should be proportionate to the benefits received.

Cost-sharing can be a two-way street. The federal government should bear an appropriate share of the costs of nonfederal projects. The federal payment should be the amount that would have been allocated to purposes deemed in the national interest if the project had been constructed by the federal government.

Each agency has applied different cost-sharing formulas. As a result, the people who were interested in getting a project authorized have sought to have that agency which would impose the lowest charge for project services construct the project. The committee has recommended that all agencies adopt a uniform approach to cost-sharing. When vendible products or services are made available they should be sold at a price which will cover the cost of providing them.

In his letter of transmittal to Congress on January 17, 1956, President Eisenhower noted some of the highlights of the report as follows:

> The policies set out in the report embody a framework within which the federal government, with state and local governments and other nonfederal interests, may cooperate to develop our water resources.
>
> . . . it recognizes that there are a multitude of water developments which are more appropriate for regional, state, or local activity.
>
> The report points out that the principles which recognize water rights as property rights should be accepted. . . .
>
> Organizational changes are recommended to coordinate more closely federal and nonfederal activity and to make possible more effective executive guidance. The intent of these proposed changes is to provide the states and local water resources agencies a more adequate voice in the planning and development of projects. . . .

As I speak today I again want to emphasize the enormous task confronting the American people in the prob-

lem of supplying adequate and suitable water for the multiple essential modern uses. Water constitutes the lifeblood of the economy, the prosperity and the health of every community. Each community and each region must jealously guard its vital interest in water. That can only be done if local interests retain an aggressive and substantive role in the basic tasks that need to be performed in the development and utilization of the resource.

Recommendations

Think of the federal government as an entity that can be helpful in some of the broad aspects of the work. For those responsibilities the various departments of the government are progressively adjusting and adapting their programs.

The report of the Presidential Advisory Committee on Water Resources Policy represents the best thinking in the executive branch of our government developed through long months of hard study. I recommend it as a guide for proper federal activity and as an associated suggestion for a continuation and an expansion of the fine constructive and indispensable local work that the members of the American Water Works Association are performing.

Cause of Water Shortages

Support for John Murdoch's thesis of "too cheap water" (*see* p. 925) actually beat the thesis into print when the July issue of *Nation's Business* presented a report by the staff of the US Chamber of Commerce on "How's Business? Today's Outlook." Discussing natural resources among the other phases of the business world, the Chamber's staff said:

> One of the principal reasons so many Americans suffer from water shortages is their insistence on bargain rates for water. Revenues from sale of water are insufficient to support the development of adequate supplies.
>
> Many water works systems are attempting to supply a necessary service with the least possible cost and investment. These penny-pinching operations are a far cry from the water departments of large industries which recognize water as an essential raw material of production. Modern boards of directors in industry now include in their plans an adequate water supply, and they spend the necessary money for surveys, development, treatment, operation, and waste disposal.
>
> Municipal water systems should take a page from industry's book and convince their boards of directors that higher water rates and additional revenue are necessary if growing demands for water are to be met.
>
> Businessmen can help improve their local water supply system through their local chambers of commerce or service organizations.

The Missouri River

Panel Discussion

A panel discussion presented on May 8, 1956, at the Diamond Jubilee Conference, St. Louis, Mo.

Introduction—*John W. Cramer*

A paper presented by John W. Cramer, Partner, Fulton & Cramer, Lincoln, Neb.

MANY hundreds of thousands of people are very dependent, in one way or another, upon the mighty Missouri.

Changes have taken place in the river; some of them are changes brought about by definite intent and design. These are exemplified by the mammoth works already completed, those under construction, and still others which are only now being planned by the US Army Corps of Engineers. Other changes have taken place which are just as significant, although they have happened gradually as a result of the vast increases in water loads imposed on the river by demands for sanitary and industrial supplies. Similar demands have been made on the river's surface and subsurface tributary waters. Superimposed upon this complex pattern are the whims of nature and the variable conditions of rainfall and runoff.

The river is being taxed to its utmost to serve the population of the basin. Many communities with needs which have barely been met have, of course, begun to cast about for a reason for their difficulties. They have begun to wonder what direction their problems will take.

As is true with any problem involving many interests, the point of view of one individual or group does not give all the answers. This group of discussers, therefore, is made up of members of federal, state, and municipal governments. They represent various areas of activity and interest concerning the Missouri River.

Reservoir System—*Wendell E. Johnson*

A paper presented by Wendell E. Johnson, Chief, Eng. Div., Missouri River Div., US Army Corps of Engrs., Omaha, Neb.

The phenomenal growth in demand for water to meet the expanding needs of municipal, industrial, and agricultural purposes is rapidly becoming one of the nation's gravest domestic problems. Control and conservation of available water resources is thus becoming an economic necessity of the first order if the consumptive water demands of a nation whose population may reach 200,000,000 by 1975 are to be met.

Although this discussion is concerned with water in the Missouri River Basin, the conditions discussed are broadly symptomatic of a general

problem which is common to the entire nation. The disastrous floods of New England and the West Coast within the last year, contrasted with the incidence of serious droughts during the same period in the Midwest, point up the fact that the water resources problem is multipurpose in scope. Therefore, the viewpoints from which the problem is to be approached must be multipurpose.

Multipurpose Approach

The multipurpose approach was the basic concept upon which the authorized Pick-Sloan Plan was designed in the Missouri Basin. It made possible an integrated and comprehensive program which could serve all the interests and areas of a basin whose patterns of rainfall and water supply are widely diversified. Actually, water supply for municipal and industrial expansion was only an incidental element in a program in which the major specific benefits are flood control, irrigation, navigation, and hydroelectric-power production.

These points have been made in order to emphasize the fact that, in the decade since construction of the Pick-Sloan program began, water supply, as an independent and important factor in its own right, has become a very significant element in the basin. One of the important benefits which has already resulted from completed portions of the program is the increased, improved, and more stable water supply in cities and industrial areas along the Missouri River, all the way from Sioux City to the Missouri's mouth. Some national leaders in the field of water resources are presently advocating that water supply for consumptive use should be a specific requirement of any comprehensive river control program.

As a member of the US Army Corps of Engineers, the author feels that his principal function in the present discussion is to comment on the effect of the Missouri Basin program on quantity of flow—that is, the regulation of flow which will be achieved by the program. Because the Corps of Engineers is interested in the effect on quality as well as quantity, however, it has cooperated with health authorities and others in programs which seek to give more information on that aspect.

Description of Program

Active construction work in the Missouri Basin, shown in Fig. 1, has been under way for many years. The navigation project on the lower river, for example, was begun in 1929 and the Fort Peck Project was begun in 1933. The present comprehensive program was approved by Congress in the 1944 Flood Control Act, and construction on this expanded program was initiated in 1946.

Upper Basin

The program includes a number of tributary reservoirs which are designed primarily to store water for irrigation and power development. Frequently, these reservoirs also include a specific storage allocation for flood control. Most of them have been designed and built by the Bureau of Reclamation, but the amount of flood control storage to be included and regulations for its use are established by the Corps of Engineers under the cooperative provisions of the 1944 Flood Control Act. About nine of the upper and western tributary reservoirs have been completed or are under construction, and about 45 are yet to get underway. The reservoirs which are in operation include: Canyon Ferry near Helena,

Mont.; Tiber, on the lower Marias River in Montana; Boysen, on the Big Horn River in Wyoming; Heart Butte, on the Heart River in North Dakota; and Shadehill, on the Grand River in South Dakota.

Main-Stem Reservoir System

Downstream, the backbone of the program is the main-stem reservoir system located in eastern Montana and the Dakotas, and it is this portion of the program which will be of the greatest interest in this discussion. The main-stem reservoir system includes six major reservoirs in Montana and the Dakotas. The principal statistics relating to these reservoirs are given in Table 1.

TABLE 1

Location and Capacities of Six Major Reservoirs in Montana and the Dakotas

Reservoir and Location	Storage Capacity *acre-ft*	Ultimate Power Capacity *kw*	Status
Fort Peck, Mont.	19,600,000	165,000	In operation
Garrison, N.D.	23,000,000	400,000	In operation
Oahe, S.D.	23,600,000	425,000*	Under construction
Big Bend, S.D.	500,000*	120,000*	Authorized
Fort Randall, S.D.	6,300,000	320,000	In operation
Gavins Point, S.D. and Neb.	500,000	100,000	In operation

* Data are tentative and subject to revision.

The magnitude of the system of main-stem dams is difficult to visualize without actually visiting the individual projects, of which four are nearing completion and in partial operation. The dams are earth-fill structures, sometimes as long as 2 miles, with concrete spillways and outlet works. They will ultimately create a chain of inland lakes stretching in an almost continuous line for 800 miles along the river. The capacities of the larger reservoirs are second only to Lake Mead, and there are no other earth dams of similar sizes elsewhere. The degree of control which they will afford has no conterpart in the river basins of the world, except possibly the contemplated development of the Nile in Africa and the planned program on the Colorado River.

Size alone is not the true measurement of their importance, however. It is the integrated method of control made possible which is the consideration vital to this discussion. Their combined capacity of 73,500,000 acre-ft is nearly three times the average annual flow of the Missouri at Sioux City. This permits storage of a tremendous volume of water to carry the river valley through prolonged drought periods such as that of the 1930's. Their design was not determined by flood control requirements, irrigation, navigation, or power generation alone, however, but by a combination of these important needs, plus domestic and industrial water supply and consideration of downstream pollution abatement. Water supply and pollution abatement, incidentally, are specifically listed as purposes of the program in the original Pick Plan. The reservoirs will also provide attractive lakes which

will serve as recreation centers for a large area.

Lower Basin

In the lower basin, the program includes a number of tributary reservoirs which are primarily for flood control along the tributaries and lower main stem. In some of these reservoirs, conservation storage will also be included for river regulation. In this area, Harlan County on the Republican River, Kanopolis and Cedar Bluffs on the Smoky Hill River, and Webster and Kirwin on the Solomon River are all in operation. Tuttle Creek on the Blue River is under construction and, in addition, a number of smaller reservoirs, primarily for irrigation and local flood control, are in operation in the upper Republican Basin. Of the larger reservoirs presently authorized for the Kansas River Basin, Glen Elder on the Solomon River, Wilson on the Saline, Milford on the lower Republican, and Perry on the Delaware remain to be started. The need and justification for other reservoirs are under consideration.

Bank Stabilization

Along the main stem of the Missouri, from Sioux City to the mouth, a program of bank stabilization has been under way for many years. The Missouri River is a meandering stream and, in the past, has occupied almost every square foot in the flood plain from bluff to bluff. The bank stabilization program will confine the river to a series of easy, continuous bends and thus protect the adjacent farm land, cities, bridges, and other installations from destruction by erosion. Incidentally, virtually every water works installation along the Missouri River below Sioux City is located on a site protected by the stabilization works. The confinement of the channel will also provide a 9-ft navigation channel from Sioux City to the mouth, connecting with the great inland waterway system. A series of agricultural and municipal levees is also being constructed from Sioux City to the mouth which will protect over 1,500,000 acres of farm land, and the cities of Sioux City, Council Bluffs, Omaha, Kansas City, and many smaller towns.

Program Benefits

As the construction program proceeds, new projects are continually being placed in operation and the benefits of the program are being realized in increasing measure each year.

Flood Control

Progress on the main-stem reservoirs is such that a high degree of flood control is already assured for the upper Missouri. Local protection projects have been completed at a number of locations and have served to avert serious flood damages in a number of instances. Perhaps the most spectacular incident occurred at Omaha and Council Bluffs in 1952 when the completed levee projects, which were designed for a flow of 250,000 cfs, had to withstand a record-breaking flood of 400,000 cfs. Some idea of the progress which is being made can be gained by the fact that, if a similar flood were to occur today, the Fort Peck, Garrison, and Fort Randall reservoirs would reduce the flow past Omaha to less than 100,000 cfs, which is well below full banks. Such a runoff, in fact, would be welcome today because it would assist in filling the reservoirs.

Irrigation

Irrigation developments are progressing more slowly, but 68,400 acres of land have been placed under irrigation since 1946 and projects under construction will add 354,800 acres more when completed.

Navigation

Navigation has made great strides in recent years because channel improvements and river regulation have provided barge operators with a dependable channel which averages 6½–7½ ft in depth at critical points. Since 1952, commercial tonnage has increased from 52,000 tons to 415,000 tons in 1955. Towing companies have added new equipment and ports are improving their facilities to accommodate the increased traffic. Ultimate traffic is expected to reach at least 5,000,000 tons.

Power

Hydroelectric-power generation is increasing rapidly as new units are added. As of May 1956, three units with a total name-plate capacity of 85,000 kw were in operation at Fort Peck, two units with a total capacity of 160,000 kw were in operation at Garrison, and eight units with a total capacity of 320,000 kw were in operation at Fort Randall. Another 80,000-kw unit will be added at Garrison during the summer of 1956 and power generation will commence at Gavins Point in the fall. Total generation in the fiscal year 1955 was approximately 1.2 billion kilowatt hours, and in 1956 it is estimated that a total of 2 billion kilowatt hours will be generated. Revenues in the fiscal year of 1956 are estimated at $7,000,000.

Water Supply

One of the most important effects of the program is the stabilization of flows which will be of significant benefit to water supply and pollution abatement. Within the past few years, the urgent necessity of providing these measures has become apparent to the public generally, as well as to the health authorities.

The growth of water consumption in America during the last half century has been six times faster than population increases. The President's Materials Policy Commission estimated that by 1975 the demand for water would be double that of 1952. These facts are important in the Missouri Basin, where more than 2,000,000 people are supplied with water from the Missouri River.

With the regulation provided by the main-stem reservoir system, it has been possible to smooth out the flows of the Missouri and assure communities along its path an ample supply for an expanded population and for industrial growth, as well as for navigation. In 1954 and 1955, for example, during the normal low-water months of August–October, as much as three-fourths of the flow at Kansas City came from water impounded by the reservoir system. At all times, the water released from the reservoir has been sufficient to meet the minimum flows established by the USPHS and the states of South Dakota, Nebraska, Iowa, Kansas, and Missouri. These minimum flows are given in Table 2. As reservoir storage is added to the major tributaries in the lower basin, including the Kansas River, it will be possible to extend and improve the stabilization of these flows to an even

greater degree, including improvements to water supply and pollution abatement on the tributaries themselves.

Although the releases from Gavins Point during the winter of 1955 were always above the minimum set by the USPHS, some difficulty was experienced in the lower Missouri River. The three factors primarily responsible for the difficulty were: [1] ice jams occurring in the vicinities of Blair, Neb., and St. Joseph, Mo., which temporarily lowered flows below minimum levels; [2] an all-time low in tributary flows (at Kansas City, for example, the flow from the Kaw River was only 400 cfs and this was not enough to keep the sewage flushed out in a uniform manner); and [3] a rapid increase in the sewage being discharged into streams—with chemical wastes, particularly, reaching alarming levels in some locations.

TABLE 2

Minimum Flows for Three Cities

Location	Flow—*cfs*		
	Jun.–Sep.	Jan.–Feb. and May–Dec.	Mar.–Apr. and Oct.–Nov.
Sioux City, Iowa	6,100	3,670	2,745
Omaha, Neb.	8,500	5,100	3,825
Kansas City, Mo.	12,700	7,620	5,715

It is clearly understood, of course, that dilution alone, resulting from reservoir releases, cannot solve the entire problem. Even on the Missouri River, primary treatment, at least, must be provided, and until this is accomplished, the job will not be done.

In addition to the effect of the reservoir program on quantity of flow, there are several important effects on water quality. The reduction in the sediment carried by the stream has already had important effects on the turbidity of the flow at Yankton, Neb., Sioux City, Iowa, Omaha, Neb., and other points. The turbidity at Omaha, which, with normal summer flows, would be 2,000–6,000 ppm, is now 500–1,000 ppm.

This reduction in turbidity also produces other effects. Because sunlight can now reach into the water in the reservoirs and downstream from the reservoirs, the growth of plankton has increased considerably, as compared to earlier conditions of high natural turbidities. As a result of a very comprehensive investigative program established by the USPHS, the growth of these plankton has been forecast with considerable success and the Yankton plant has been able to make advance adjustments to avoid any adverse taste and odor effects.

The reservoir system also averages out the hardness of the water, thus simplifying the job for water treatment plants and homeowners. Plankton action in the reservoir also reduces the total hardness of the water under some conditions.

Operation of Main-Stem System

Operation of the main-stem reservoir system has been underway for some time. The Fort Peck Reservoir was placed in partial operation in 1938 and power operation began in 1943. Fort Randall began initial operation in 1953 and power operation in 1954. Initial operations at Garrison began in 1954 and power operation in 1956. Operation of Gavins Point Reservoir began in 1955 and power generation will begin in the autumn of 1956.

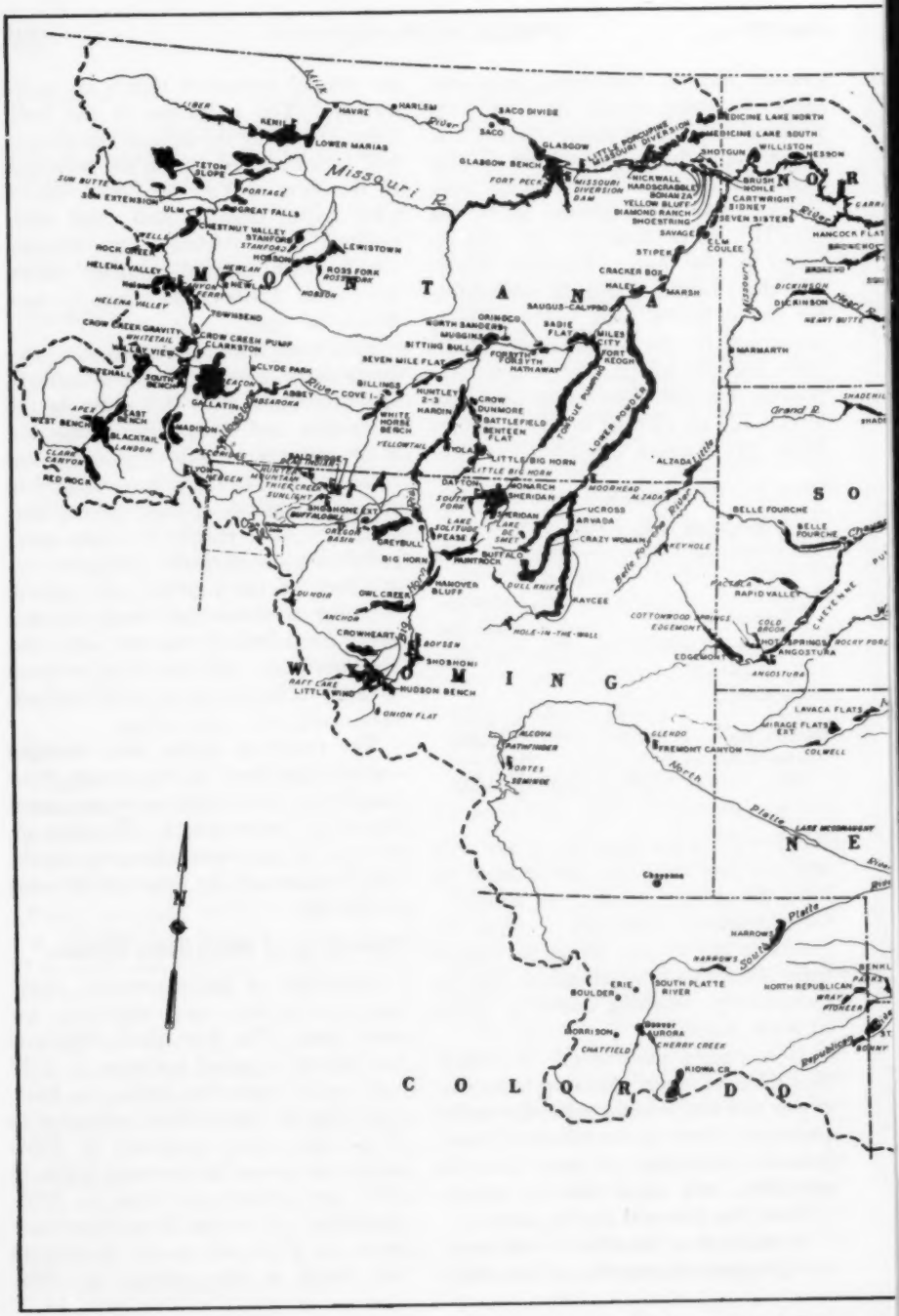

Fig. 1. Water and Land Resources

The black areas indicate reservoirs, irrigation, flood control, or w

oment in the Missouri River Basin

d. The circles indicate flood control and the flags, power plants.

Partial operation of the Oahe project will begin in 1959.

Operating a large reservoir system such as the main-stem system involves consideration of the probable supply, as determined by runoff forecasts and the expected demands for flood control storage, irrigation, navigation, water supply, pollution abatement, and power. These considerations involve a number of federal agencies, the seven states on the Missouri River, and interests along the lower Mississippi. Although these many and diverse interests and considerations might be expected to imply great difficulties in developing a workable system of operation, the actual transition from construction to operation has been very smooth; a great many people, in fact, are hardly aware that the plants are already operating. The great success in achieving the transition was probably made possible by the cooperative approach of all interested agencies toward the planning and execution of the program. A Reservoir Control Center has been established in Omaha which does the detail work on the development of the operation plan. This center obtains from all available sources data on the basic requirements for each of the basic functions of the reservoir system. Each year, for example, the requirements for water supply and pollution abatement are reported by the USPHS, which gets these data in collaboration with the various states. The irrigation requirements are obtained from the US Bureau of Reclamation, in collaboration with the states. In this manner a complete catalog of requirements is built up. At the same time, a forecast of available water for the next period is developed from data supplied by the US Weather Bureau, the USGS, and other sources. The Reservoir Control Center then takes these estimates and develops a tentative annual operating plan which is aimed at supplying all of the needs of the basin to the optimum extent consistent with expected available water.

The tentative plan thus developed is then submitted to all the states and the federal agencies for review and comment. A meeting of these interests is held to discuss the tentative plan in detail and to work out any apparent differences so that a plan suitable to all interests can be evolved. The plan, as thus developed, is then published and distributed. Actual execution of the plan is carried out by the Reservoir Control Center with close and frequent consultation with all federal and state agencies.

This system has worked exceedingly well. Naturally, there have been some differences of opinion. Interests in the Dakotas, for instance, have occasionally urged that power be given a greater priority in operation planning, navigation interests have requested that the navigation season be lengthened, and some lower-basin interests have requested that releases be increased to assist in pollution abatement. Generally, however, the people are realizing more and more clearly that the program was authorized and constructed to serve all functions and that the proper plan is the one which serves those functions best.

For the next few years, as the reservoirs are being filled to normal levels, flows will have to be husbanded with extreme care. After the filling has been accomplished, the normal flows of the river should provide ample water for all uses.

The specific outlook for 1956 is good, with a forecast for inflows which,

although they are below the normal 25,000,000 acre-ft, are definitely above the level of last year, when the flow was only 17,000,000 acre-ft, and somewhat above the previous year, when the flow was only 19,000,000 acre-ft. With the 1956 expected flow, minimum flows for public health can be more than met, a full navigation season will be possible, all irrigation demands will be answered, and all essential power needs can be realized. Specifically, a flow of 35,000 cfs will be maintained at Kansas City, Mo., until late October or early November, and thereafter the flows will be maintained at a minimum of about 12,000 cfs.

Conclusion

Although the scope of this article does not include consideration of the national water policy, the author believes that all who have an interest in the problem of water supply understand that long-range planning, coordination, and integration are necessary to the successful operation of a reserve system. These factors make possible the prevention of the tragic waste which has occurred in the past, and supply a positive action to meet the demands of a great and growing nation. The experience in the Missouri Basin has helped to show the way toward sound programing in this important field.

Acknowledgment

The author would like to express his appreciation for the excellent cooperation the US Army Corps of Engineers has received from municipal, state, and federal public health officials in the planning and operation of the reservoir system, and especially to Glen Hopkins of the USPHS, with whom the US Army Corps of Engineers has worked very closely for 8 years.

——Water Quality and Quantity—*George E. Ferguson*——

A paper presented by George E. Ferguson, Chief, Program Control Branch, Water Resources Div., USGS, Washington, D.C.

The water resources of the Missouri River proper and of the Missouri Basin as a whole are being rather intensively measured and evaluated during the planning, design, and construction phases of the Missouri River Basin program (*1*). Because of the magnitude of the development, the hydrology of the basin will undergo significant change. Many additional water facts will be required to define the future pattern of streamflow, the occurrence of ground water adjacent to the stream channels, and the changes in quality of each. Operations of control works will be guided by the future stream flow regimen, and water plant chemists will probably have to make adjustments to treatment processes as the new pattern of water quality characteristics develops.

A study which examines past and present water quality data and identifies the effect of development work upon water supplies study cannot, of course, be nearly complete at this early stage of basin development. Current changes reflect only the primary stage of transition to a rather fully controlled Missouri River, and it is

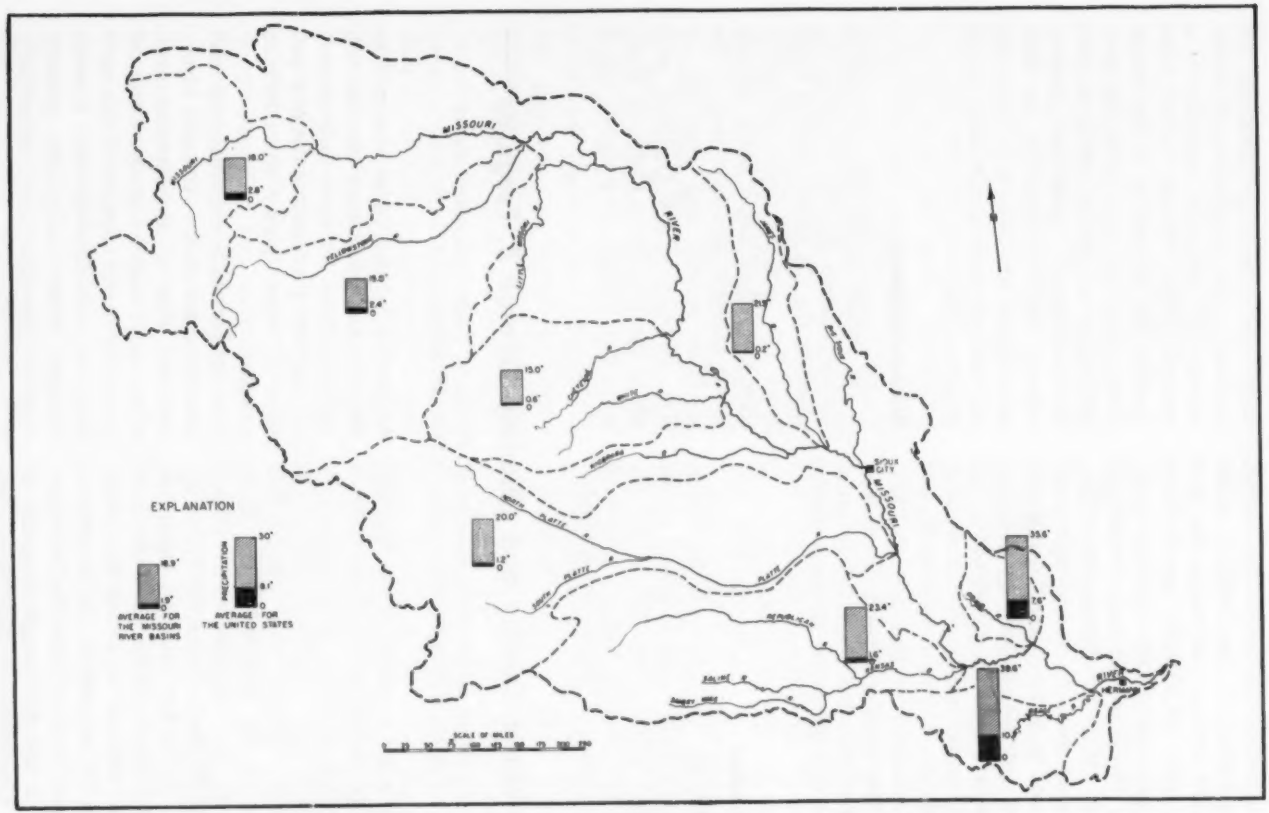

Fig. 2. Precipitation, Runoff, and Evapotranspiration in Missouri River Basin

In the bar graphs, precipitation is indicated by the total bar, runoff by the black portion, and evapotranspiration by the hatched portion.

much too early to determine what effect the stabilized river operations will have on quality of water and ground water occurrence. This paper, therefore, gives a hydrologic picture based only on investigations made to date.

Water Use

The water resources of the Missouri Basin can be effectively introduced in terms of their utilization. Although the average use per square mile for the nation is higher than it is for the Missouri River Basin (73,000 gpd for the nation, as compared to 30,000 gpd for the basin) the average use *per capita* for the basin is higher than that for the nation, with a 2,140-gpd average in the basin as compared to the national average of 1,350 gpd.

Current estimates of water used in the basin, as compared with the nationwide pattern, are given in Table 3. The percentages indicate withdrawal uses and do not include such uses as hydroelectric-power generation, navigation, and recreation. Each time water is withdrawn for use it is measured, but it may be used again or recycled several times before it is discharged as waste water. The extent of recycling is unknown, but it is estimated that about half the water withdrawn is consumed by evaporation or transpiration. It is interesting to note that the amount of water leaving the basin, as measured near the mouth of the river, averages between three and four times the estimated amount withdrawn in the basin, or about seven times the amount consumed. The flow at the mouth of the river, which is the unconsumed water or residual, will be of greater beneficial use when the control dams are in operation.

TABLE 3

Water Usage in Nation and Missouri River Basin

Use	Percentage of Total Usage	
	Nation	Missouri River Basin
Rural (domestic and livestock)	1	2
Public supplies	8	5
Irrigation	41	68
Industry (self-supplied)	50	25

Basin Runoff

Runoff within the Missouri River Basin varies greatly, as do the factors governing the amount of runoff which results from a given precipitation.

Figure 2 compares precipitation, runoff, and the evapotranspiration losses in the Missouri River Basin with the average for the United States as a whole, and shows variations within the basin. The bar graphs represent the annual average runoff measured at the downstream gaging station of each selected subbasin and the average annual precipitation as determined from a map of average annual precipitation. The difference between the precipitation (total bar) and the runoff (black portion of bar) is considered to be the annual evapotranspiration (hatched portion of bar) in the basin.

It will be noted that streams such as the Yellowstone and upper Missouri River, which drain the Rocky Mountain regions, have a much higher runoff for the same or less precipitation than do the streams which enter the Missouri River in its middle portion. The greatest runoff in the basin occurs near the downstream end of the river.

the hatched portion.

The net effect of the contributions of the various tributaries can be seen in Fig. 3. The main-stem reservoirs are located above the station at Sioux City, which has a drainage area of 314,600 sq miles, or 59 per cent of the entire basin. The station at Hermann, Mo., near the mouth, has a drainage area of 528,200 sq miles, which represents 99.8 per cent of the basin total. Figure 3 shows not only the magnitude of the annual average flow, but also the year-by-year variation. Other significant points indicated are the following:

1. No significant trend is apparent in the long-range runoff records at either of these two key locations on the river

2. The record shows rather clearly a tendency for above-average runoff to persist for several years, and the same is true for the below-average years; this tendency is partly caused by the carryover effect of hydrologic conditions during the preceding year

3. The outstanding long period of below-average flows of the 1930's and the early 1940's is more than an interesting hydrologic event. It was this contribution of nature which brought the Missouri Basin Program into being.

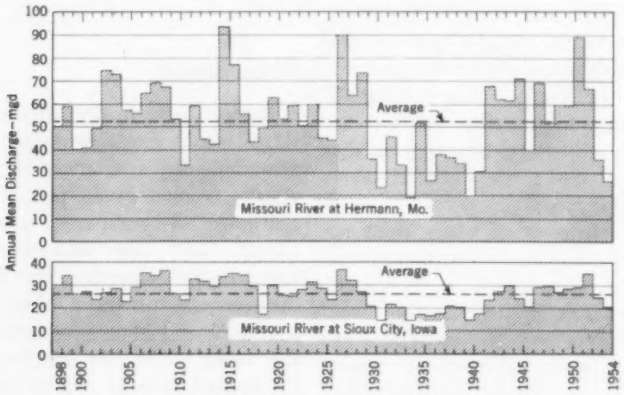

Fig. 3. Annual Discharge of Missouri River at Selected Stream-gaging Stations, 1898–1954

Water Quality

Those who have an active interest in the hydrology of the Missouri Basin are conversant with the quantitative aspects of the Missouri River, but water quality of the main stem is a less familiar subject.

The quality of the river water can be likened to a vast quantity of chemical solution being circulated and processed in an industrial plant. At predetermined places in the reaction, the chemist adds additional substances in solution, each capable of exerting a change in accordance with the quantity, concentration, and temperature of the reactant. Precipitation and resolution; gas formation, solution, and loss; evaporation, and concentration—all are part of, and contributed to, the end product.

Historically, the Missouri River has been a turbid stream rich in sulfate

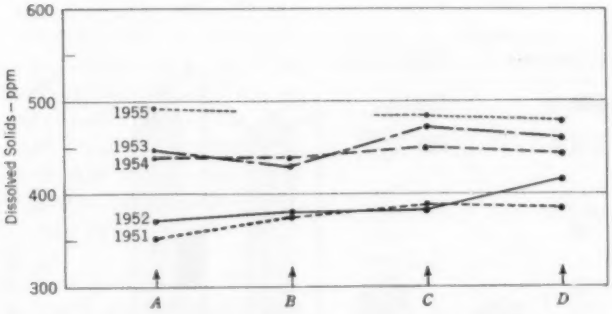

Fig. 4. Average Dissolved Solids in Missouri River, 1951–55

Samples were taken at the following locations: A—*Sidney, Mont., on the Yellowstone River;* B—*Williston, N.D.;* C—*Pierre, S.D.; and* D—*Nebraska City, Neb. Sampling points* B, C, *and* D *were all on the Missouri River.*

and high in hardness. The overall quality of the river water reflects the widely variable geologic, hydrologic, and cultural environment to which the river and its tributaries are exposed. One of the earliest published records for water quality of the main stem was that made by Clarke (*2*), who gave the results of analysis of composites of daily samples at Florence, Neb., for October 1906–October 1907, shown in Table 4. The averages of the components of that analysis are markedly like those of a recent analysis at Nebraska

TABLE 4

Summary of Chemical Analysis of Missouri River Water *

Constituent	Missouri River Near Florence, Neb. October 1906–October 1907		Missouri River at Nebraska City, Neb. October 1952–September 1953	
	Concentration—*ppm*			
	Range	Mean†	Range	Mean‡
Calcium	45–102	65	50–81	62
Magnesium	7.9–38	20	12–35	18
Sodium and potassium	34–72	49	39–77	59
Bicarbonate	146–337	203	166–280	191
Sulfate	81–237	168	119–257	177
Chloride	5.5–15	8.9	8.7–31	16
Nitrate	0.3–5.5	1.8	1.0–5.2	3.1
Dissolved solids	300–663	454	348–589	462
Turbidity	40–7,200	1,726		
Hardness (as $CaCO_3$)	153–411	246	180–307	228

* Values for iron and silica are not included.
† Data are for arithmetical average.
‡ Data are for discharge-weighted average.

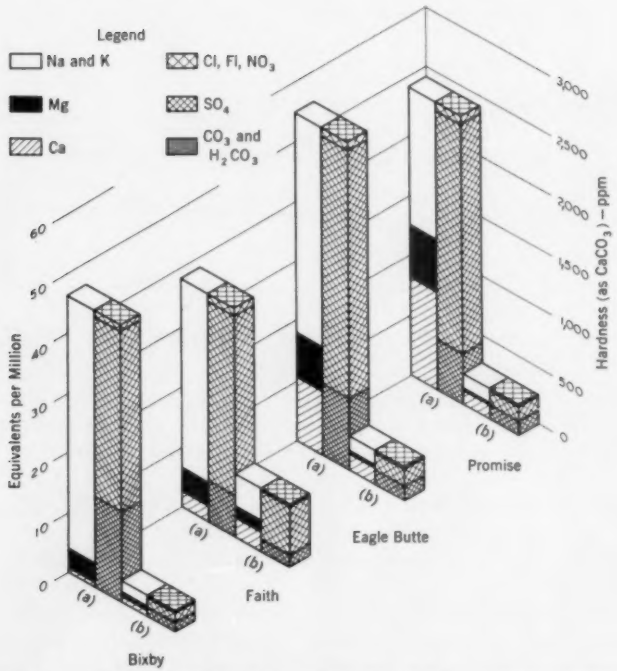

Fig. 5. Principal Mineral Constituents of Moreau River, S.D., at High and Low Flows

Data are for the following: Bixby—(a) 1.4 cfs, Sep. 14–30, 1949, (b) 7,600 cfs, Apr. 15–17, 1950; Faith—(a) 1.1 cfs, Sep. 11–30, 1947, (b) 4,900 cfs, Jun. 25, 1947; Eagle Butte—(a) 1.2 cfs, Dec. 21, 1950, (b) 12,200 cfs, Apr. 7, 1950; and Promise—(a) 1.4 cfs, Jan. 15, 1951, (b) 13,400 cfs, Apr. 7, 1950.

City, Neb. This is especially true for period October 1952–September 1953, when the dissolved-solids content was almost identical with that obtained in 1906–07. It is interesting to note that the ranges in concentration of the principal ions in the early record are not greatly different from those in the 1952–53 sampling period. It should be recognized, however, that the composite analysis tends to mask the true range in constituents that is normally found in day-to-day sampling. Also, comparison of short periods of record should be made with reservation.

Preliminary hydrographic studies for three stations operating since 1951 on the main stem of the Missouri River at Williston, N.D., Pierre, S.D., and Nebraska City, Neb., indicate that in any single year there is about a two-fold range in the dissolved-solids concentration in daily samples as compared to a wide range in streamflow (*3*).

For the period of record, 1951–55, the range in concentration of dissolved solids (for daily samples) at any station was between twofold and threefold. The maximum range in the concentration of principal constituents shown in Table 4 is of the same order except for the less prominent sodium and chloride ions for which the range is greater.

A summary of data for the 5 years of record at Pierre and Nebraska City and for 4 years at Williston, N.D., as given in Table 5, shows that downstream from Williston the increase in average dissolved-solids content and hardness of the river water is quite small. This relationship, shown in Fig. 4, held equally well during 1951 and 1952, when flow past Nebraska City was about twice that at Williston, and in 1954, when flow at Nebraska City was only about 40 per cent greater than at Williston. The close relation of the water quality of the Missouri River at Williston and that of the Yellowstone River at Sidney, Mont., is apparent from Fig. 4.

The above observations are more enlightening when one considers that fluctuations in quality of tributary streams are rapid and range widely, as, for example, the Moreau River, which drains parts of northwestern South Dakota (*see* Fig. 5). The dissolved-solids concentration and hardness fluctuate by a factor of 10 or more between high and low flows. The effect on the main stem of the poor quality of low flow from Moreau River, however, is compensated for by the larger effect of better quality high-flow water. A somewhat better picture of the basin's surface water quality is given in Fig. 6, which shows an average value for hardness and dissolved solids at specific sampling locations on principal tributaries and on the previously discussed main-stem stations. Some of the values for tributaries are partly estimated and, where the sampling station is well upstream from the confluence with the main stem, the quality may be improved in

TABLE 5

Summary of Runoff and Weighted Averages for Dissolved Solids and Hardness of Water, Missouri River, 1951–55 *

Water Year	Runoff *1,000,000 acre-ft*	Dissolved Solids *ppm*	Hardness (as $CaCO_3$) *ppm*
Yellowstone River at Sidney, Mont.			
1951	8.245	352	175
1952	9.486	371	186
1953	6.843	448	215
1954	6.664	443	211
1955	6.506	491	233
Missouri River at Williston, N.D.			
1951	15.76	376	186
1952	21.06	377	190
1953	15.79	430	215
1954	16.47	431	215
Missouri River at Pierre, S.D.			
1951	15.23	389	186
1952	26.49	385	193
1953	18.61	473	219
1954	17.08	450	213
1955	14.65	481	226
Missouri River at Nebraska City, Neb.			
1951	32.34	384	208
1952	42.24	415	213
1953	28.50	462	229
1954	22.90	443	223
1955	19.88	476	235

* For 1951, 70–80 per cent of runoff is represented; for other years, 100 per cent is represented.

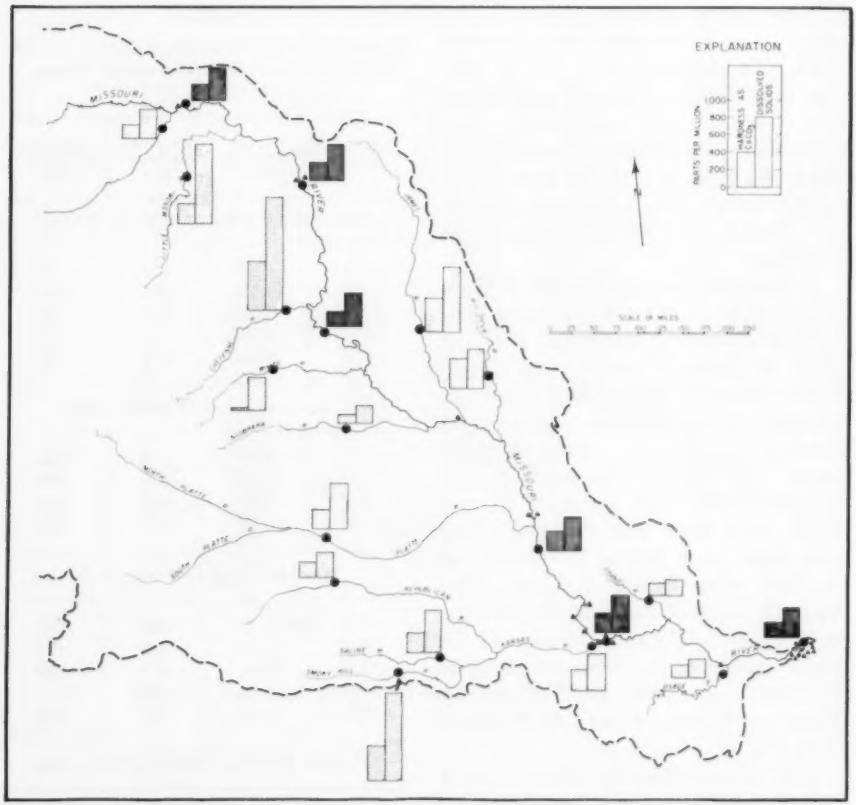

Fig. 6. Hardness and Dissolved Solids at Selected Sampling Sites in the Missouri Basin

The dark-colored bar graphs are for Missouri River sampling sites, and the light-colored are for tributary sampling sites. A black circle indicates chemical quality sampling site and a black triangle indicates a larger municipality served with water from the Missouri River.

places by inflow in the more humid lower reaches.

In Fig. 7, water quality at two stations in the Missouri River basin is compared with that in other basins. The bar diagrams are based on the unit equivalents per million rather than on parts per million, the conventional unit, so that the constituents can be shown in proportion to their true chemical values. The equivalents per million are obtained by dividing parts per million of the constituent by its combining weight. There is great contrast in the soft waters of low mineral content in the Savannah River, Ga., and the hard waters of higher mineral content for the Missouri River and, particularly, the Brazos River, Tex., and the Colorado River, Ariz.

Twenty-four public water supplies, serving a total population of more than 2,000,000, draw water from the Missouri River. Much of the population served is in or near Omaha, Kansas City, Mo., and St. Louis. The quality of Missouri River water for public supplies is rather poor by usual standards of measurement. The concentration of dissolved solids is somewhat high, averaging 400–500 ppm. The hardness averages more than 200 ppm at most places, and the turbidity is excessive, reaching a maximum at some places of probably 20,000 ppm (silica scale). For public supply, therefore, the water requires extensive treatment, including softening in most instances.

Adjacent Ground Water

Throughout its course, the Missouri River is generally an effluent stream—that is, its surface is usually below the level of the water table in the unconfined aquifers on either side of the river, and, in general, is considerably below the piezometric surfaces of such confined (artesian) aquifers as the Dakota sandstone and the Codell sandstone member of the Carlisle shale. Thus, the Missouri is a "gaining" stream; as it wends its way seaward its flow is augmented by effluent seepage from the hydraulically connected water table aquifers and, in some places, by artesian flow. An example of the latter is to be found at Fort Randall Dam, where artesian water of the Codell sandstone member discharges directly into alluvium in the bed of the Missouri River below the dam.

Prior to water resource developments in the basin, the water table and the river stage were in a state of relatively fixed equilibrium. Under these conditions the water table sloped from the higher lands, where the ground water is recharged by precipitation, down to base level (the level of the river). Increases in ground water storage resulted either from increased local rainfall, which caused a temporary and local rise of the water table, or from floods in the river, which both recharged the ground and raised the base level locally so as to back up the ground water flow. Recharge resulting from floods in the river caused temporary storage in the unconfined aquifers of a wedge-shaped body of water, thickest end toward the river, which was later released to the river as the flood crest passed. Then the normal river aquifer relationship was reestablished.

The established water table profile intersects the river level at the near bank and slopes upward and inland at a degree determined by the transmissibility of the geologic materials and the amount of recharge that builds up and maintains the water table. This profile fluctuates up and down within certain natural limits.

What happens when dams and irrigation works are established and operated? The ground water records of the USGS in the vicinity of the Missouri River control structures are too few and limited to prove what theory and practical experience elsewhere would indicate is happening, or may happen, in the basin. Many more observation wells in the aquifers connecting with the river are needed to tell the story.

Figure 8 shows a 3-month record of stages in the Missouri River at Jefferson City, Mo., and water levels in a shallow well tapping the aquifer about 2,000 ft from the river at the

same place. The water table is shown to rise and fall in response to changes in stage of the river, but with less amplitude. Fluctuations in bank storage are shown in the illustration, and not permanent changes in aquifer storage. Thus, when the water table stands at a higher level than the river, discharge takes place from the aquifer to the stream, but when the stage of the stream is above the water table, the river recharges the aquifer.

Ground water hydrologists have long recognized that, if the base level of discharge of an aquifer is raised, the associated water table will readjust to the new base level, and, other things being equal, it will ultimately rise to a new position above and nearly parallel to the old water table profile.

Filling a river reservoir is one way of raising the local base level of ground water discharge. The amount of ground water to be discharged remains about the same, but the slope of the profile toward the reservoir tends to be a little gentler, because the water is moving through a greater total thickness of rock. Also, the amount to be discharged may be a little less because

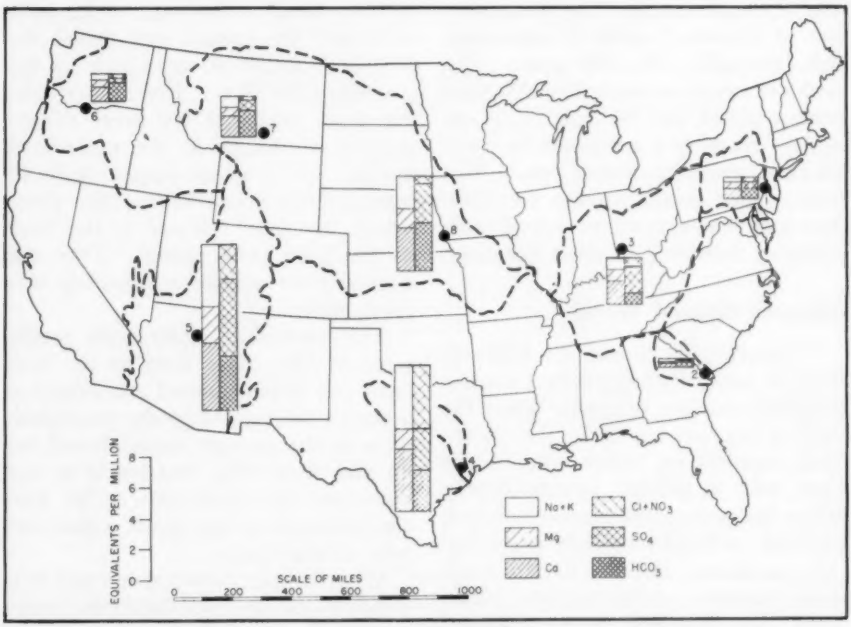

Fig. 7. Chemical Composition of Water in Several US Basins

Data are for the following: [1] *Delaware River at Trenton, N.J., 1951;* [2] *Savannah River near Clyo, Ga., 1940;* [3] *Ohio River at Cincinnati, Ohio, 1951;* [4] *Brazos River at Richmond, Tex., 1951;* [5] *Colorado River near Grand Canyon, Ariz., 1951;* [6] *Columbia River near Rufus, Ore., 1951;* [7] *Yellowstone River at Billings, Mont., 1951; and* [8] *Missouri River at Nebraska City, Neb., 1951.*

the water table may rise near enough to the surface to promote discharge by evaporation and transpiration.

Development works on the river may affect the natural ground water levels in adjacent banks in another manner. The silt-free water released from reservoirs has the ability to pick up sediment, cleaning out the bed and increasing the freedom of interconnection between the ground water and the river, and, hence, the readiness with which the ground water level becomes adjusted to the river level.

Effects will also be noted in connection with some artesian aquifers. At Fort Randall Dam, which was closed in July 1952, it has been noted that, in a nonflowing artesian well tapping the Codell sandstone member, the piezometric surface has risen 21.5 ft since impounding began. From 8.0 ft in 1953 and 11 ft in 1954, the annual rise has decreased to about 2.5 ft in 1955. During the same period, the piezometric surface, as measured in a well tapping the Codell sandstone member about 10 miles upstream from the dam, has risen 12.5 ft. Eight feet of this rise occurred between Jan. 4, 1955, and Feb. 1, 1956. Wells tapping the Codell a few miles north of the river showed no rise in 1953–55.

Plugging of some flowing artesian wells tapping the Dakota sandstone upstream from Fort Randall Dam has reduced waste of artesian water and may have caused a diminution of the composite cone of depression in and near the reservoir. Further reduction of cones of depression around other wells, which were flowing but unplugged, probably took place as the reservoir filled because the hydraulic gradients in the vicinity of the flooded wells decreased. The piezometric head in one artesian well in the Dakota sandstone at Pickstown apparently has increased about 1 ft since 1952. Possibly higher water levels also have resulted, at least in part, from the loading of the earth's crust above the aquifer as the reservoir imposed its added weight. Such head increases are temporary, however, and disappear when the effect is dissipated in the aquifer and associated beds.

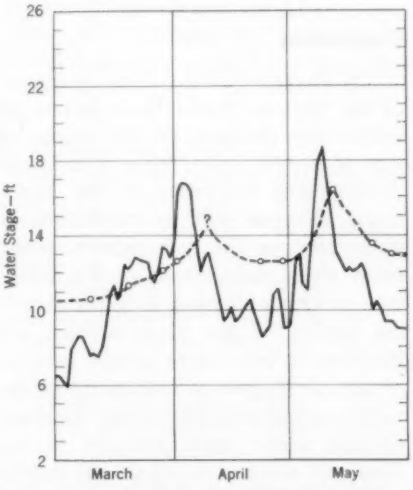

Fig. 8. Well Record and Missouri River Stages at Jefferson City, Mo., 1953

The solid line indicates data for the Missouri River and the dotted line for a shallow well which was about 2,000 ft from the river.

Water levels in the water table aquifers of some irrigation projects of the Missouri Basin are known to have risen since irrigation began. In the more intensely irrigated parts of the Angostura project in South Dakota, for example, the average water level has risen 9 ft in eight observation wells since 1953; the most spectacular rise

was about 30 ft in one well. In some places, previously dry geologic materials are now beginning to accumulate excess irrigation water and are becoming what might be called "artificial" aquifers. Two examples of this are the alluvium of the Bessemer terrace of the Arkansas River, near Pueblo, Colo., and the Ralston terrace of the Shoshone River, near Powell, Wyo.

Conclusion

The character of the water resources of the Missouri River Basin is not yet sufficiently changed by the works of man to permit a clear view of the post-development hydrology of the basin. Some changes will be comparatively great, such as the flow pattern of the main river and certain of the tributaries. Other changes, as in the chemical quality of the river waters, are likely to be less severe largely because of the fair degree of uniformity of the waters at various points along the river. Ground water levels adjacent to the river will reach a new point of stabilization in relation to the new pattterns of river levels, and water use, both consumptive and nonconsumptive, will continue to grow, as it has in other parts of the nation.

Acknowledgment

The author is indebted to Walton H. Durum, Kenneth A. MacKichan, Garald G. Parker, and James K. Searcy, of the staff of the USGS, Washington, D.C., for their participation in the preparation of this paper. Acknowledgment is also made of the assistance and field information furnished by Paul C. Benedict, George H. Taylor, Harry C. Bolon, Charles F. Keech, James R. Jones, and Frank A. Swenson, of the USGS field organization in the Missouri River Basin.

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Pollution Conditions—Dwight F. Metzler

A paper presented by Dwight F. Metzler, Chief Eng., Kansas State Board of Health, Lawrence, Kan.

The lower Missouri River supplies water to 1,800,000 persons living in sixteen cities along its course, as well as to many industries; consequently, river pollution has been of concern to the cities and the public health authorities for many years. The report of the first study of pollution by Allen McLaughlin of the USPHS was made in 1913 at the insistance of Samuel J. Crumbine, Kansas state health officer. The results, even then, indicated reason for concern, and the concern has increased with the growth of cities and industries and the accompanying increase in waste load.

Recognizing the need for more current information, state sanitary engineers for South Dakota, Nebraska, Iowa, Kansas, and Missouri agreed in

December 1949 to make a joint study of the Missouri River from Yankton, S.D., to its junction with the Mississippi. The Missouri River Basin Office, Division of Water Pollution Control of the USPHS, was largely responsible for bringing the states together. It agreed to compile the data and to do the major work in preparing the report. The states evaluated sources of wastes, established river sampling stations, collected stream samples, made laboratory analyses, and secured data concerning municipal and industrial water use. The study was planned as a truly cooperative program, with each agency contributing according to its resources and ability. The conclusions and recommendations made are incorporated in a joint state-and-federal report of the Lower Missouri River Basin Water Pollution Investigation, dated October 1952.

The study revealed serious bacterial pollution and excessive organic pollution in some stream reaches. Although the Missouri River has a great capacity for absorbing organic pollution, bacterial pollution follows generally the pattern established in other large rivers. Unfortunately, dilution alone is not a satisfactory solution in the control of bacterial pollution.

There are 270 municipal sewer systems tributary to the lower Missouri River. These serve a combined population of 1,400,000. In addition, industrial wastes discharged to municipal sewer systems add a population equivalent of 1,500,000 to give a total waste load equivalent of 2,900,000 persons, as shown in Table 6. Existing treatment reduces this by about 10 per cent. Seventy-five industrial establishments have separate sewers discharging directly to the river, adding a waste equivalent of 1,690,000 persons. This gives a total waste equivalent of 4,590,000 persons. Figure 9 shows the effects of this pollution in median coli-

TABLE 6

Sources of Pollution for Lower Missouri River Basin

State	Municipal*		Industrial†		Total Population Equivalent		Percentage Removed by Treatment
	No. of Sources	Population Equivalent—Untreated‡	No. of Sources	Population Equivalent—Untreated§	Untreated	Discharged	
Iowa	105	327,920	29	750,800	1,078,720	973,810	9.7
Kansas	18	142,980	4	39,150	182,130	163,180	10.4
Minnesota	(1) ‖						
Missouri	106	963,930	37	656,930	1,620,860	1,485,380	8.3
Nebraska	40	1,440,420	3	273,600	1,714,020	1,653,840	3.5
South Dakota	18	24,400	2	7,800	32,200	26,170	18.3
Total for lower Missouri Basin	287	2,899,650	75	1,728,280	4,627,930	4,302,380	7.1#

* Includes incorporated or unincorporated municipalities and such other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers, or other population centers.
† Includes industrial wastes discharged into municipal sewerage systems.
‡ Industries have separate outlets.
§ Organic wastes.
‖ Discharges are outside of basin.
Average for lower Missouri Basin.

form concentrations at the various sampling stations during the summer months. Water leaving Yankton, S.D., has a median coliform value of 2,300 coliform organisms per 100 ml. This climbs to nearly 100,000 at Sioux City and remains above 30,000 to well below Jefferson City, Mo.

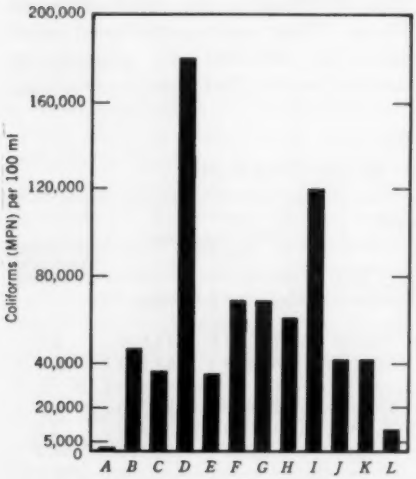

Fig. 9. Median Coliform Values for Water Plant Intakes June–September, 1950

Data are for the following: A—*Yankton, S.D.;* B—*Omaha, Neb.;* C—*Council Bluffs, Iowa;* D—*Nebraska City, Neb.;* E—*St. Joseph, Mo.;* F—*Atchison, Kan.;* G—*Leavenworth, Kan.;* H—*Kansas City, Kan.;* I—*Lexington, Mo.;* J—*Boonville, Mo.;* K—*Jefferson City, Mo.; and* L—*St. Louis, Mo.*

A typical example of the effect of upstream pollution upon raw-water quality is provided at Kansas City, Kan., where the average annual coliform concentration increased from 6,000 to 73,000 in 30 years—a twelvefold increase. Figure 10 shows the average annual coliform concentration from 1922–55.

Recognizing that the safe limits of coliform loading were being exceeded at the water purification plants in the four downstream states, the five state health departments and the USPHS agreed to a cooperative and uniform program of pollution abatement for the Missouri River below Fort Randall Reservoir.

It was agreed that each state was to have primary responsibility for abating the pollution within its boundaries and that this action should be carried out under the widely varying laws of the individual states rather than through federal enforcement. It was also agreed that the program should apply equally to each polluter and that reasonably uniform progress should be made regardless of variations in individual state laws. Full cooperation between the states and the USPHS was outlined in a plan which would leave the primary initiative to the states, with cooperative and coordinating assistance from the USPHS. It was agreed that, where joint state and federal progress reviews indicate that the reduction of pollution in a particular state is lagging seriously behind progress in the other states, the USPHS will initiate federal enforcement proceedings.

Progress

Floyd Creek, which enters the Missouri River at Sioux City, and the Kansas River, which joins the Missouri River at Kansas City, contribute the largest amount of tributary pollution. A program of pollution abatement along the Kansas River and its tributaries was started in 1950 by the Kansas State Board of Health. This

program is nearing completion, with about 43 new sewage treatment plants already finished or under construction. Located at the mouth of the river are Kansas City, Kan., with waste for a population equivalent of 730,000, and Kansas City, Mo., with sewage from 800,000 persons still going untreated into the Kansas River. In 1954, bonds were voted by Kansas City, Kan., for the first part of its program.

Sioux City has completed its plans for its sewage treatment works. Omaha needs three sewage treatment plants. Its voters approved sewer service charges at a general election on Mar. 20, 1956, to improve storm and sanitary sewers and to provide treatment "as may be required."

St. Joseph, with its multiple outlets to the river and its large meat-packing industry, faces a serious problem, but its officials have promised to proceed with the necessary planning and construction. They have scheduled a bond election for the autumn of 1956. Grease from this area is stranded on sandbars for many miles downstream, and it accumulates on the water works intake structure at Atchison.

Although progress was slow at the beginning, Atchison is now proceeding with its planning, and Leavenworth has completed plans for treating its sewage along with the wastes from Fort Leavenworth, the veterans hospital, and the federal penitentiary.

Kansas City, Mo., has not yet started an engineering study of its problem, although the matter is under active discussion. North Kansas City has purchased a plant site and has started the preparation of detailed plans. Downstream cities are moving toward sewage treatment more slowly. This is understandable in view of their relatively small size and their desire to be assured that the large upstream polluters are serious in their intentions to construct waste treatment facilities.

Effects of Flow Regulation

Since the Pick-Sloan Plan for development of the Missouri River was announced, there has been some concern on the part of water works and public health officials as to the plan's effect on the quality of public water supplies. It was this concern which led to the cooperative study in 1948 of the Kansas River Basin by Kansas, Nebraska,

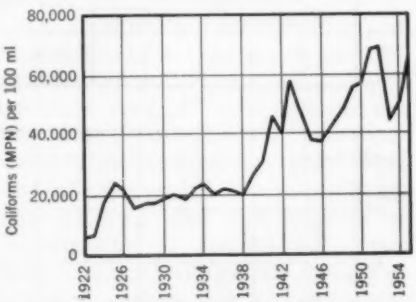

Fig. 10. Coliform Concentration of Raw Water at Kansas City, Kan., Water Plant, 1922–55

the USPHS, the US Corps of Engineers, and the Bureau of Reclamation.

On the basis of the findings from this study and other information which was accumulating, the state health departments in the Missouri River Basin asked the USPHS to investigate the effect of reduced turbidity upon algal growths. Since August, 1952, a USPHS biologist, supported by funds from the US Corps of Engineers has been studying water quality changes as related to Missouri River reservoirs. Until 1952, problems from poor biological raw-water quality had not occurred.

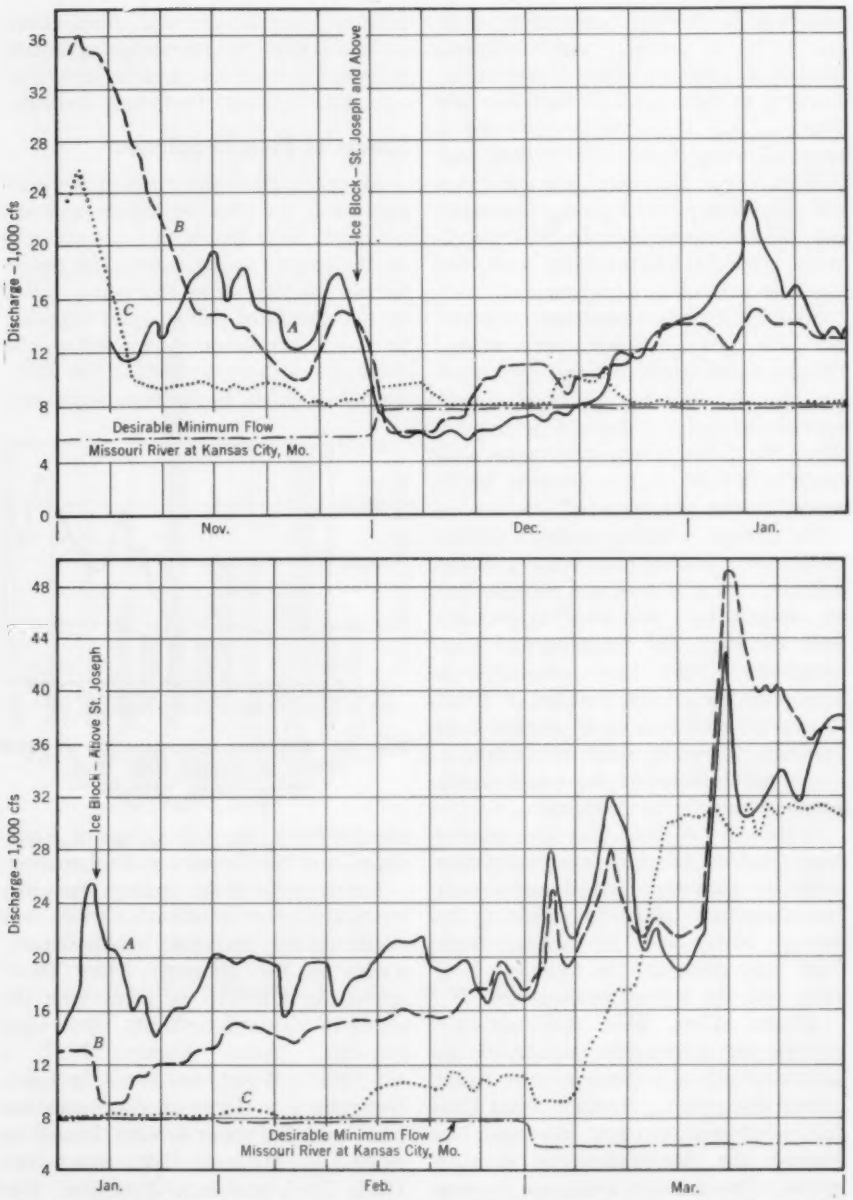

Fig. 11. Flows of Missouri River at Kansas City, Mo., and Gavins Point Dam, S.D., November 1955–March 1956

Line A represents data for natural flow of the river at Kansas City, Mo.; Line B, at Kansas City, Mo.; and Line C, at Gavins Point Dam, S.D.

The reservoirs have greatly reduced turbidity downstream. At Bismarck, N.D., 40 miles below Garrison Reservoir, turbidities averaged 957 ppm in 1953 and only 89 ppm in 1954. This entire reduction is believed to be caused by storage in the reservoir and flow regulation. Similar reductions in turbidity have been observed below Fort Randall and Gavins Point reservoirs. A marked reduction in turbidity also occurred at Omaha following regulation by the Fort Randall Reservoir.

Significant reductions in turbidity have extended to Kansas City, which is 550 miles below Fort Randall. A comparison of the average annual turbidities from 1918 to 1954 clearly reveals the reservoir influence. Prior to 1952, the turbidity averaged 2,195 ppm, with the lowest annual average being 1,450 ppm. For several years the average was above 3,000 ppm and an annual average below 2,000 ppm occurred in only 7 years during the period 1918–46, after which reservoir closures began to influence the lower river. The average turbidity has remained well below 2,000 ppm each year since 1946, and recently the reduction has been very pronounced. With impoundment in the Fort Randall, Garrison, and Gavins Point reservoirs, the average annual turbidity was 803 ppm in 1953 and 810 ppm in 1954. This reduction can definitely be credited to sedimentation in the reservoirs and elimination of the peak turbidities which have accompanied unregulated peak flows.

Reservoir storage has also caused recognizable reductions in alkalinity and total hardness. The impoundment of low–mineral content spring runoff and the chemical changes which tend to remove certain dissolved and suspended substances in impoundments are believed to be responsible for these reductions. Although average reduction in hardness at Yankton and downstream points seems to be about 10 per cent, a much greater reduction occurs in periods of peak hardness during times of minimum stream flow.

A study by the USPHS, not yet reported, indicates that reductions in turbidity, alkalinity, and hardness extend downstream to St. Louis in much the same range as reported for Kansas City, Kan. Some saving in chemicals used is reported for each water plant on the river.

As might be expected, the reductions in turbidity have been accompanied by an increased growth of algae. In 1953 and 1954, taste and odor problems occurred at Yankton, S.D., the first water plant downstream from Fort Randall Reservoir. These problems were not major and were corrected by modifications in conventional treatment. Substantially greater dosages of activated carbon and chlorine have minimized the frequency and occurrence of unpalatable finished water.

Plankton concentrations in the Missouri River were low in 1953 and 1954 until clear water occurred in and below Fort Randall Reservoir, after which concentrations greatly increased to the point of reaching nuisance levels in the water supply at Yankton in August 1953. Benthic algal growths, absent before impoundment, became prominent below Fort Randall Dam after July 1953.

On the basis of the reports made thus far on these studies, algae-induced taste and odor problems can be expected at those water plants which take water directly from a reservoir or are located a short distance below a main-

stem reservoir. USPHS engineers believe there is little danger of severe algae-related taste and odor problems developing as far downstream as Omaha, 100 miles below Yankton.

The full effect of river development and regulation is yet to be determined. The reservoir releases for navigation during the warm months, however, have not given the benefit in reduced bacterial content which might have been expected from the increased dilution. Apparently, the increased river velocities which accompany the larger releases offset the increased dilution through the reduction in flow time and consequent reduction in die-away of fecal organisms.

Water Treatment Problems

While the lower main-stem water supplies have not been troubled with algae-induced problems, some extremely difficult treatment problems have arisen downstream from Kansas City since November 1955.

The state health departments and the USPHS had previously concluded that, during the winter, a flow of 7,620 cfs at Kansas City was necessary to insure a satisfactory oxygen balance and provide for reasonable dilution of sewage and industrial wastes. Reservoir releases during the non-navigation season are planned to maintain this rate of flow, and, except for occasional ice jams, a flow of 8,000 cfs has been maintained at Kansas City for the last three winters.

In December 1955 the flow dropped to 6,000 cfs for 10 days at Kansas City because of ice jams, as shown in Fig. 11. During these lowest flows the physical quality of the water deteriorated until the Boonville water plant was forced to shut down, and other water plants downstream from Kansas City were unable to cope with the extreme tastes and odors in the raw water, which continued to recur periodically through March 1956. Debris, particularly grease balls, feathers, and particles resembling garbage, was noted on the river, and on at least two occasions the wastes had a strong odor resembling that of oil refinery waste. There is no doubt that municipal sewage, meat packing, and other industrial wastes were involved. Similar conditions have occurred at the Nebraska City and Atchison water works intakes.

Summary

Pollution is increasing and it will continue to increase until the needed waste treatment works are put into use. The five states are implementing the program for cleaning up the Missouri River through regular conferences with officials of Missouri River cities. January 1, 1959, has been set as the date for each city to start construction of primary treatment facilities; this is a major program which will take some time to finance. The cost is estimated in the vicinity of $100,000,000. That this program is overdue is shown by the difficulty being experienced in purifying Missouri River water, especially below Kansas City.

Cleaning up of the Missouri River will mean a new way of life to many industries and cities. It means major changes in existing city sewer systems. For some industries it means substantial revision of manufacturing processes. The changes cannot be accomplished at once, but it is the responsibility of each city and industry to start now. Failure to do so will result in

punitive action by the state water pollution control authorities, supported, if necessary, by federal action.

Acknowledgment

The author wishes to thank Glen Hopkins, Regional Engineer, USPHS, for supplying much of the data used in this article. For other data, acknowledgment is due the state health departments of South Dakota, Iowa, Nebraska, Kansas, and Missouri.

Experiences at Omaha—*John C. Detweiler*

A paper presented by John C. Detweiler, Gen. Supt., Water Operation Dept., Metropolitan Utilities Dist., Omaha, Neb.

In various ways, the Missouri River serves many communities as it travels from the mountains to meet and blend with the waters of the Mississippi at St. Louis. The first large city below the main-stem reservoirs which takes water from the river for processing, purification, and distribution to its citizens is the city of Omaha, Neb., and this discussion is intended to show the effect of the river improvement program on the water supply for that city.

Background

Prior to the development and actual construction of the various improvements on the river which have become effective in the past few years, there were inherent hazards in the use of this supply as a source for a city water system. The conditions observed were as follows:

1. Occasional deficiencies in quantity of water available, resulting from low river stages, caused real anxiety, particularly during winter periods when low river discharges and an unstabilized channel were coupled with ice gorge conditions.

2. The quantity of water was sometimes too great, as evidenced by the various spring floods. During the Missouri River flood in April 1952 the river stage at the intakes of the pumping station at Florence, Neb., reached a maximum of 33.8 ft, while the height in April 1956 was 7–8 ft.

3. High turbidities and attendant water treatment problems occurred during periods of heavy rainfall in the upstream watershed, particularly during the spring and summer periods. In the spring of 1932, river turbidities reached a maximum of 32,000 ppm, while the present raw-water turbidities seldom exceed 1,000 ppm.

4. The quality of raw water varied, as evidenced by a high dissolved-mineral content, particularly in the winter period when the flow in the river consisted of "spring flow" or feedback from underground sources. Occasional taste and odor problems seemed to defy treatment.

These statements are not meant to imply that the Missouri River was not a good source for a water supply; the problems of treatment were such, however, that the ingenuity of the operators was occasionally taxed to cope with the situations that developed.

But that was in the past, and the "Muddy Missouri" has been changed, if not tamed, as a result of the improvement program which has been conceived and carried out mostly by the Corps of Engineers.

Program at Omaha

In Omaha, the first phase of the river improvement program was centered around the building of a levee system below Sioux City, Iowa, for both flood protection and the development of a stabilized channel for navigation purposes. This proved beneficial to the Omaha water supply by reducing the possibility of diverting the channel from the river intakes. The levee system practically eliminated the spasmodic and unsuccessful attempts of public and private agencies to control the channel at various points along the river. This portion of the program has also improved the efficiency of the channel, resulting in lowering the river stages for given rates of discharge. At Omaha, the river intake facilities had to be lowered to adjust to the new conditions. Facilities at Omaha are now available for coping with practically any river stage.

The next phase of river improvements pursued by the federal government involved the construction of the dams on the main stem of the river and the operation of the reservoir system. This change in the river has been most noticeable in its effect on water quantity and quality. First it was observed that the flow or discharge of the river had been stabilized to reduce peak flows and increase the flow during the previous low-flow periods, particularly in the late summer and early fall. Even the winter flows have been supplemented, possibly because of the releases of water for power generation as well as the releases for the maintenance of adequate flow for sanitary purposes. Also, the raw-water quality has been improved, peak turbidities have been greatly reduced, and there has been an averaging of the components of turbidity and mineral content of the raw water, all of which should result in reduced treatment costs. Plant chemists report that they miss some of the turbidities which were present a few years ago, however, and the water clarification problems will probably require the use of different chemical combinations to produce proper flocculation. High turbidities were not always objectionable, particularly if they were caused by the light-colored clays originating in the Dakotas and similar to bentonite, which dropped out like magic. The material remaining in suspension was an efficient coagulant aid. Since the closing of the upstream dams this material does not appear.

It is also anticipated that the storage of spring and summer river flows in the reservoir system will reduce the hard-water periods normally observed in midwinter, and will tend to average out the mineral content throughout the year to produce a more acceptable raw water.

In considering the effect of the reservoir system on water quality, it is anticipated that the problem of tastes and odors has changed and is possibly more complicated now. The releases from the nearest dam at Gavins Point, some 135 miles above Omaha, are reported to have very low turbidity and, as the water moves south, particularly during the summer months, the environment for the growth of plankton or algae is ideal. Because the reservoir system is barely of age, there has not been much opportunity to determine the final effect and requirements on the treatment of the water for taste and odor control.

Summary

Reviewing the general effect of the Federal River Improvement Program as it pertains to the Omaha water supply, it can be said that this supply has benefited from development of a stabilized channel, regulation of the river to produce supplemental flow when needed, the practical elimination of the hazards of floods, the improvements in raw-water quality consisting of lower peak and average raw-water turbidities, and at least a change in the taste and odor problem.

Effects of Main-Stem Dams on Supply at Kansas City, Mo.—*James B. Ramsey*

A paper presented by James B. Ramsey, Chief Engr. and Supt., Water Dept., Kansas City, Mo.

Kansas City, Mo., can well be grateful for the dams on the upper Missouri River. If it had not been for the discharge from these dams, Kansas City would have experienced prolonged water shortages during the last three drought-ridden summers. The intake capacity of the city was not sufficient to get the water from the river at the stages that would have existed naturally. The discharges from the dams and the resultant higher river stages made it possible for the city to meet a 57 per cent increase in maximum day consumption in recent years. Many innovations and additions had to be resorted to in order to meet these demands, but all of them would have been useless if natural river stages had existed.

Changes in Flow

Winter flows have not been a problem at Kansas City, although many operators downstream from Kansas City seemed to have more than the usual amount of pollution. Some operators thought that the normal flow in the river was being curtailed by the dams. Because of these complaints a check was made of records for flow past Kansas City for many years back. These records showed that, before any of these dams were built, there were many winters when the flows in the river were much smaller than they were during the past winter. Furthermore, a comparison of the flow records at Yankton, S.D., with those at Kansas City show that during the minimum month for the past winter almost all of the flow at Kansas City was coming from these dams. The conclusion was that the flow in the river would have been disastrously low if the normal flow had not been supplemented by the discharges from the dams.

Turbidity and Pollution

In regard to turbidity and pollution, Kansas City has benefited from the dams because of dilution and a more uniform flow, particularly during the warm months of the year.

In comparing Kansas City turbidity records for the last three consecutive drought years with similar drought years of the 1930's, before any of these dams were in service, it was found that the average turbidity in the river is now only 25–50 per cent of what it had been. Somewhat similar results are expected in years of average runoffs. Records indicate very clearly, however,

that maximum turbidities will continue to be as high as they were before the dams were built. This fact is important for those designing new plants in the area.

Pollution has been favorably affected by the dams, and maximum coliform counts have been dramatically reduced. There may be other factors involved which are not yet realized, but it is known that the discharge from the dams dilutes the pollution during the months when the normal flow would be very low, thereby reducing the extreme maximums that have occurred in the past.

Because of the lower turbidities, there have been no algae problems at Kansas City. There may be algae problems in the reservoirs above the dams, but any resultant problems from this are not expected to carry as far downstream as Kansas City.

Hardness

To date, records at Kansas City show no significant change in maximum and average hardness. A change in the noncarbonate hardness that will be beneficial to Kansas City is expected, however. It is hoped that much of the noncarbonate hardness comes into the river upstream from some of the dams and will be greatly diluted by the relatively soft water in the reservoirs. It is anticipated that, at most times in the future, the noncarbonate hardness will be low enough for production of hardness of 90 ppm, little or no soda ash being used. It may be possible to produce a stable water with somewhat higher alkalinity for better protection of hot-water heaters and at lower cost than the water now being produced. This, however, is still to be proved.

Evaluation of Weather Modification Experiments

Frederic A. Berry

A paper presented on May 8, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Frederic A. Berry, Chief Scientific Adviser, The President's Advisory Committee on Weather Control, Washington, D.C.

CONSIDERING the relative inefficiency of nature's processes for making rain, it seems a marvel that we get as much rainfall as we do. It has been estimated by various meteorologists that only 5–15 per cent of the available moisture in a cloud system reaches the ground during a rainstorm. Frequently, clouds which have all the apparent exterior qualifications necessary to produce rain, fail to do so and either drift on past the frustrated farmer or dissipate into clear air.

The clouds that produce appreciable rainfall are formed when moist air is forced to rise either by topographical features (such as mountain ranges), by the interaction of air masses of different temperatures (and therefore different densities), or by local convection caused by heating of the surface air. The rising air is cooled by expansion and, if the temperature drops low enough, a cloud is formed, consisting of billions of tiny water droplets.

These droplets are extremely small, their diameters ranging from 0.00004 in. to 0.004 in., and are too light to fall out of the cloud as precipitation. Thus, some other process must occur which will form water drops large enough to fall from the cloud and reach the ground without evaporating.

At present two methods are considered to be primarily responsible for the formation of precipitation—the ice crystal process and the coalescence process. In the ice crystal process, the cloud must rise to altitudes at which the temperature is colder than freezing and both ice crystals and water drops are present. As the vapor pressure over ice is less than over water, the ice particles will grow at the expense of the water until eventually they become large enough to fall out as snow or, at warmer temperatures, rain.

The possibility of causing rain to fall prematurely, or of augmenting naturally formed rain, hinges upon the fact that water vapor requires a nucleus of solid matter about which to freeze at temperatures warmer than $-40°F$. These freezing nuclei, as they are called, are quite variable in their behavior. Their numbers may vary a thousandfold or more from day to day and from place to place. Sometimes, apparently, they are too few to accommodate all the water vapor molecules which might otherwise become ice crystals. Moreover, they are unable to serve as freezing nuclei until the temperature has fallen to some value much colder than freezing. The specific value, of course, depends upon the composition of the individual nucleus, but, in general, temperatures of 5°F or colder are required for most natural nuclei. Table 1 compares the tempera-

tures at which some of the solid particles normally found in the atmosphere are effective as freezing nuclei with those at which carbon dioxide and silver iodide—the two "artificial" substances most commonly employed—are effective. As a result of this range of behavior, the existence of subcooled water drops—that is, liquid water at temperatures colder than freezing—is a common occurrence in all developing cloud systems which extend above the freezing level.

Thus, weather modification, as currently practiced, depends primarily upon the use of a substance (such as silver iodide) which will be effective as a freezing nucleus at temperatures warmer than those required by naturally occurring nuclei. (The warmer the reaction temperature of the artificial substance, the more effective it is likely to be.) Such substances are injected as trillions of minute particles into subcooled cloud systems. Theoretically, if the cloud has not reached an altitude at which the temperature will permit natural nuclei to function, the artificial nuclei will serve to form the necessary ice crystals for the production of rain, as shown in Fig. 1. On the other hand, if such an altitude has been reached, the artificial nuclei, acting at warmer temperatures, will increase the amount of rainfall from the cloud system, as shown in Fig. 2.

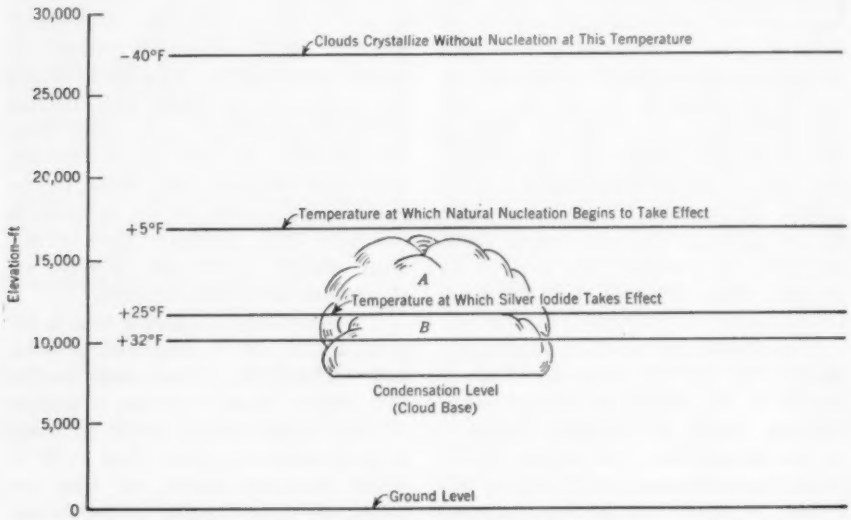

Fig. 1. Theoretical Nucleation Effects, Type I

The theoretical effect of artificial nucleation of a cloud which has not reached the level of natural nucleation is shown. Water content of Zone A *can be affected by silver iodide nucleation, while that of Zone* B *is unaffected by nucleation.*

Practical Difficulties

The usefulness of this theory depends, quite obviously, upon the frequency with which a layer of subcooled water droplets occurs in a cloud system. At some stage in the "life span" of a storm cloud, natural proc-

esses should provide sufficient ice crystals to convert the entire cloud, above the freezing level, to ice. At this stage, therefore, the introduction of artificial nuclei will have no effect. The data available indicate that storm cloud systems are sometimes composed entirely of ice crystals, sometimes of mixed particles of water and ice. At other times they include a deep layer of subcooled water droplets. Unfortunately, the relative frequency of occurrence of each condition is unknown.

Another important question, largely unanswered at the present time, is under what circumstances and how frequently artificial nuclei released on the ground will be carried to the altitudes necessary for effective action by the natural atmospheric processes. It seems reasonable to expect that, when moisture-laden winds blow against a mountain barrier, the artificial nuclei will be forced to rise with the air from the surface and enter the clouds usually formed under these circumstances. The chances of accomplishing this over flat country are certainly somewhat less, depending primarily on the highly variable weather conditions. The use of aircraft to release the artificial nuclei eliminates this problem but creates a number of others, including those arising from the necessity of seeding continuously for long periods over large areas, which in turn is dependent upon the cost of aircraft operation, maintenance, and availability. Moreover, the weather conditions most favorable for cloud seeding are also those most hazardous and difficult for flying.

In any attempt to evaluate weather modification experiments, the amount of additional precipitation produced by the cloud-seeding operations is the crucial factor. In order to determine it, it is necessary first to be able to estimate how much rain would have fallen naturally, if no cloud seeding had been conducted. This is difficult for a number of reasons, including the following:

1. The amount of precipitation at a specific location cannot be forecast with any degree of accuracy.

2. Precipitation normally varies greatly from time to time and place to place. Local showers, during which it rains on one side of the street and not the other, are familiar phenomena.

As the effects which must be identified are smaller than variations between individual storms, it is necessary to deal with comparatively long-term averages in which the natural variations will tend to average out and any artificial effects will have an opportunity to demonstrate themselves. At present, the best way to accomplish this is by statistical analysis.

TABLE 1

Temperature Activity of Ice Crystal Nucleation Particles

Substance	Source	Temperature of Activity—°C	
		Threshold	Complete
Carbon dioxide		0*	0*
Silver iodide		− 4	− 9
Loam	Rugby, N.D.	− 8	−23.5
	Bruel, Wis.	−13	−22.5
	Coeur d'Alene, Idaho	−16	−27.5
	Oakley, Kan.	−15.5	−32
Clay	Guilderland, N.Y.	−11	−24
Loess	Hanford, Wash.	−11	−24
Soil	Wolf Point, Mont.	−12.5	−27
	Baggs, Wyo.	−12.5	−26
	Nevada	−12.5	−26
Sand	Agate, Colo.	−24	−31.5
Ash	Crater Lake, Ore.	−11.5	−27.5
	Paricutin, Mexico	−22.5	−29
Kyanite		−18.5	−27.5
Dust	Phoenix, Ariz.	−19	−28
Marl	Ravenna, N.Y.	−19.5	−28
Bentonite	Montana	−21.5	−28.5
Diatoms		−30.5	−40
Spores		−35.5	−39
Kaolin	Georgia	−23.5	−32

* Activity caused by temperature of −78°C. Anything colder than −39°C produces similar effect.

Evaluation Techniques

One or more control areas adjacent to, and upwind from, the target area are chosen. The target and control areas and rainfall stations used to evaluate one specific operation are shown in Fig. 3. Using stations for which the longest past records of rainfall data are available, the amount of rainfall in the target area during all past storms is compared with the amount in the control area for the same period. In this way, it is possible to obtain a "regression"—a mathematical estimate of the average amount of rain that should fall in the target area when a known amount falls in the control. This estimate has a certain inherent probability of error which depends primarily upon how closely the target and control rainfalls have been related to each other in the past. This can be expressed as a correlation coefficient, 1.00 indicating perfect agreement (which is never found) and 0.00 meaning there is no relation between the two. In the evaluations performed by the Advisory Committee on Weather Control, correlation coefficients of 0.80–0.90 were usually obtained.

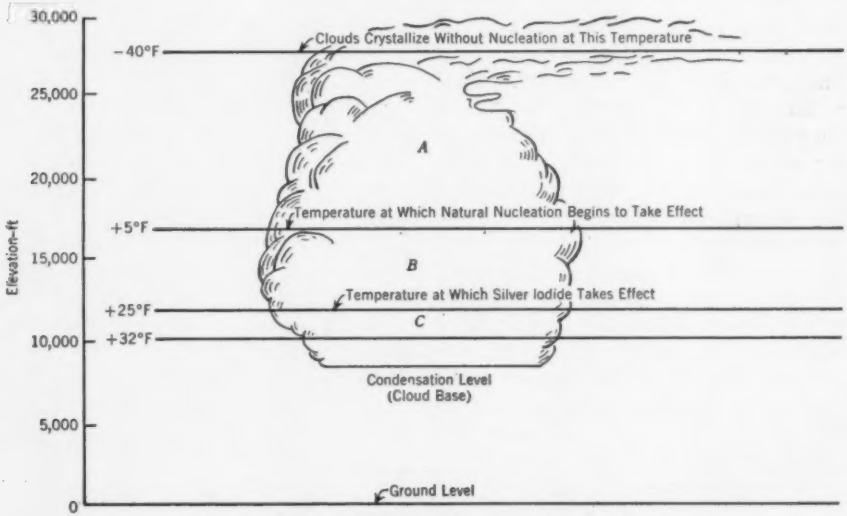

Fig. 2. Theoretical Nucleation Effects, Type II

The theoretical effect of artificial nucleation of a cloud which has reached the level of natural nucleation is shown. Water content of Zone A *can be affected by natural nucleation; that of Zone* B, *by silver iodide nucleation. Zone* C *is unaffected by nucleation.*

To detect appreciable increases in precipitation by statistical means with reasonable confidence, not only a high target-control correlation but also a large number of seeded cases is required. Consequently, wherever possible, the evaluations of the advisory committee have been performed for individual storms, rather than on an annual or monthly basis, and were lim-

ited to projects which have been in operation for a number of years.

Figure 4 shows the actual regression line for the Santa Barbara County, Calif., project for all January storms of record prior to the commencement of cloud-seeding operations (there were 75). The correlation coefficient is 0.87. The line through the center, from lower left to upper right, is the mean of all the points and is used for estimating what the target precipitation for a given storm in January would be under normal unseeded conditions. The control area precipitation is measured horizontally, the target area vertically. To make the data more amenable to statistical analysis, it is transformed to the arbitrary units indicated along the axes. The upper line, slightly curved, has an exact statistical interpretation which will not be discussed here; to oversimplify somewhat, it indicates the limit above which the point representing any future unseeded storm has one chance in ten of falling. It may also be taken roughly to represent the limit below which 90 per cent of past storms have plotted out. If seeding has a great effect, therefore, the majority of seeded storms should plot out well above the line, leaving little question as to the result. As the overall effect, however, is apparently in the neighborhood of 10 to 15 per cent, it is necessary to obtain the average of a number of storms to estimate whether the effect is real or the result of chance natural activity. This is done by standard statistical methods.

The six graphs in Fig. 5 show the results of the Advisory Committee's

Fig. 3. Rain Gage Sites, Santa Barbara Project

Location of rain gages used in the evaluation of Santa Barbara County, Calif., cloud-seeding project are shown. Target gages are indicated ●, control gages ○.

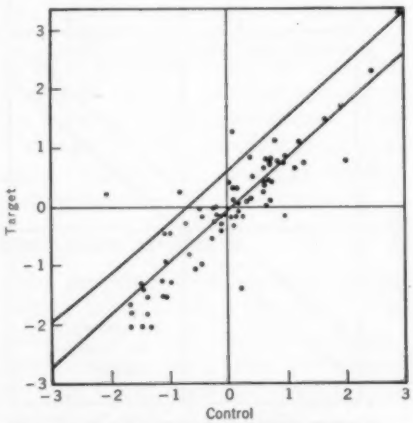

Fig. 4. Target-Control Relationship Chart

Points indicate target-control precipitation relationship for Santa Barbara project, prior to cloud seeding, for January storms in the historical period 1931–50. Units indicated along axes are arbitrary statistical transformations of data. The correlation coefficient is 0.87.

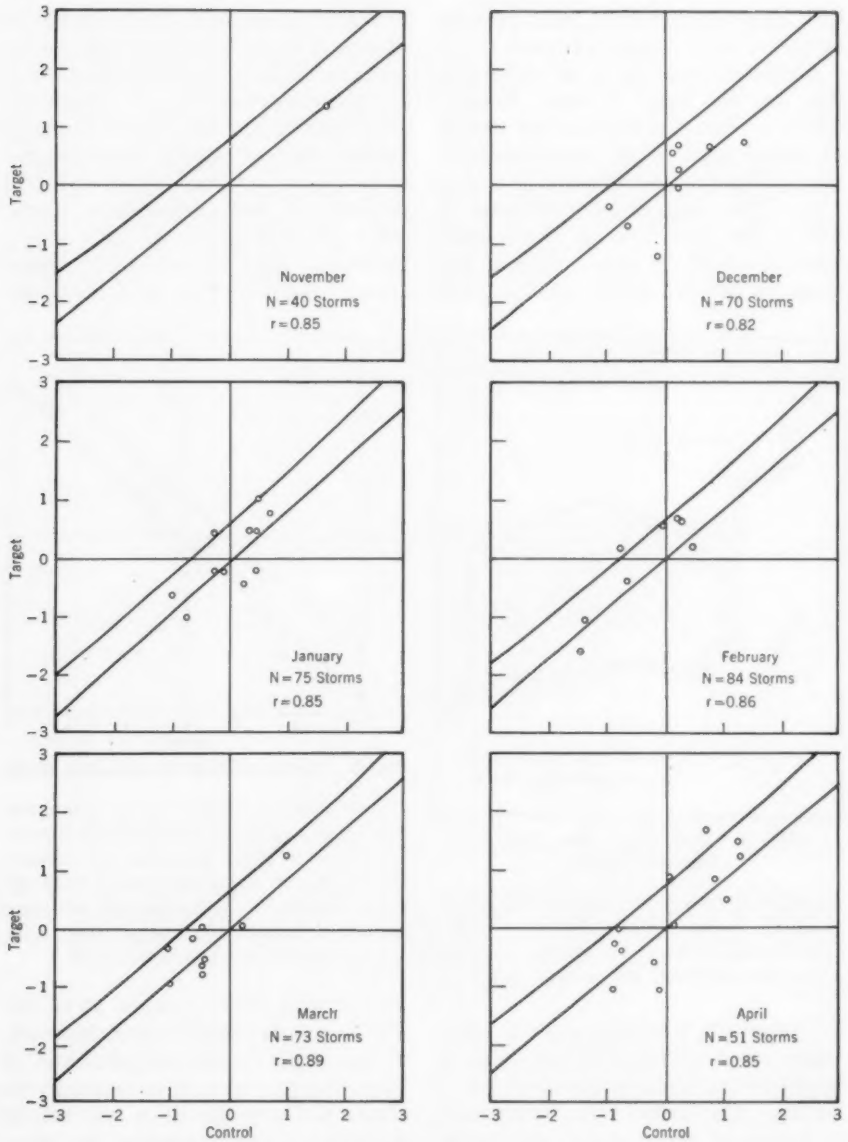

Fig. 5. Target-Control Relationships, Seeded Storms

Target-control relationships for seeded storms in the period November–April are shown for the Santa Barbara project. N represents number of storms upon which regression is based, r the correlation coefficient.

evaluation of this project. The historical storms, upon which the regression is based, are omitted to permit clearer visualization of the seeded storms. During the seeding operations, there was a total of 51 seeded storms. The results of analysis show that the increase due to seeding is significant, with one chance in ten of being in error. This increase for the 51 storms corresponds to an average increase of 16 per cent in rainfall above what might have been expected from past history.

In some of the operations, the majority of the precipitation fell as snow which, in snow courses, is difficult to measure consistently from year to year, or fell in areas where no precipitation measurements are made. Where the target is the watershed of a river, for which good runoff records are available, it is attempted to establish a correlation between the runoff from the target watershed and that of an adjacent unseeded watershed.

Figure 6 shows the historical relation between the runoff of the south fork of the San Joaquin River near Florence Lake, Calif., and the Merced River at Pohono Bridge. The total runoff for April–August is used, as this is considered to represent most truly the snowpack melt in this area. The correlation, 0.96, is unusually good. The seeded years are plotted as open circles. Again, the analysis indicates that the increase in runoff is significant, with one chance in ten of being in error. The average increase for the 5 years is estimated to be 10 per cent.

Four other projects in the West yielded similar results, the average increases during the seeding periods being estimated at 9–18 per cent. Three other western projects showed no statistically significant increases; the data in these three cases are not good and it could also be said that the projects have not been in operation long enough to permit a decision to be reached with the data available.

Considering the inherent errors possible in this type of analysis, positive results in any one case would be interesting but not very conclusive. The estimated increases for individual projects are only estimates and the actual amounts, which will never be known, may differ appreciably from those given. The Advisory Committee, however, is encouraged by the fact that results in similar projects are all of the same general magnitude and agree with independent theoretical calculations made by several eminent meteorologists.

Limitations of Results

In assessing these results, several factors must be kept in mind. All projects for which statistically significant increases were found are located in West Coast states and have the following, as well, in common:

1. The topography of the target area is such that, during storm conditions, the seeded air is forced to rise by the prevailing winds to altitudes where the artificial nuclei should be effective.

2. Seeding operations were conducted primarily during the winter and spring storms, when widespread cloud systems prevail and the freezing level is comparatively low.

3. Good correlations were found between target and control areas.

4. The projects have all been in operation for a number of years.

When other areas of the United States and the warmer seasons of the year are considered, the problem becomes much more complicated. Here the second method of rain formation,

the coalescence process, enters the picture. It has long been recognized that in the tropics most rain falls from clouds which do not extend up to the freezing level and consequently something other than ice crystals must be responsible for the formation of the raindrops. It has been proposed, and in recent years substantiated, that in these clouds there are a number of droplets larger than

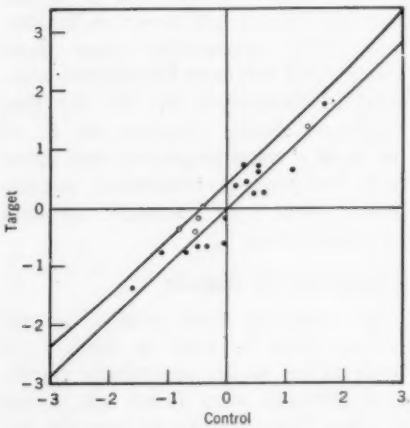

Fig. 6. Target-Control Runoff Relationship

Runoff relationship for the period April–August, before and after seeding, is shown. The target and control areas for this project were, respectively, the South Fork of the San Joaquin River, and the Merced River at Pohono Bridge. Points indicated ● are for the historical period 1933–50, those marked ○ for the operating period 1951–55. The correlation coefficient is 0.9567.

the rest. Because of differing rates of rise or fall, these larger drops will "sweep out" and collect the smaller ones, eventually growing to raindrop size. Recent investigations have shown that a considerable portion of the summer rainfall in the Middle West, and probably the East as well, originates in portions of the clouds warmer than freezing. In the summer months, moreover, the freezing level is quite high and the probability of artificial nuclei reaching the altitudes necessary for effectiveness is much smaller than in winter. The relative contribution to the total rainfall made by the two processes is a subject of considerable disagreement among meteorologists, and it must be kept in mind that cloud seeding as currently practiced can only affect the ice crystal process.

The West Coast states have a comparatively simple rainfall cycle, with cool rainy winters and warm dry summers. On the other hand, in the Middle West the greater proportion of the annual rainfall occurs during the warm months of the year. Figure 7 shows a few typical rainfall distributions. It can be seen that the greater part of the Omaha rainfall, typical of the Great Plains states, occurs during the warm months when the freezing level is high. Washington is typical of the East and Northeast states, with rainfall more or less evenly distributed throughout the year.

With the above in mind, the Advisory Committee does not feel that its findings can be extrapolated to other regions nor to the warmer seasons of the year. Much more research and experimentation must be done and a better understanding of the precipitation process attained before even a qualitative estimate can be made of the ability of cloud seeding to increase rainfall during the warm seasons and over flat country.

Conclusions

A few years ago, many people were quite enthusiastic about the potential of cloud seeding—there were to be no more droughts, the deserts would bloom, severe storms would be eliminated. The enthusiasm is still in evidence but seems to be somewhat re-

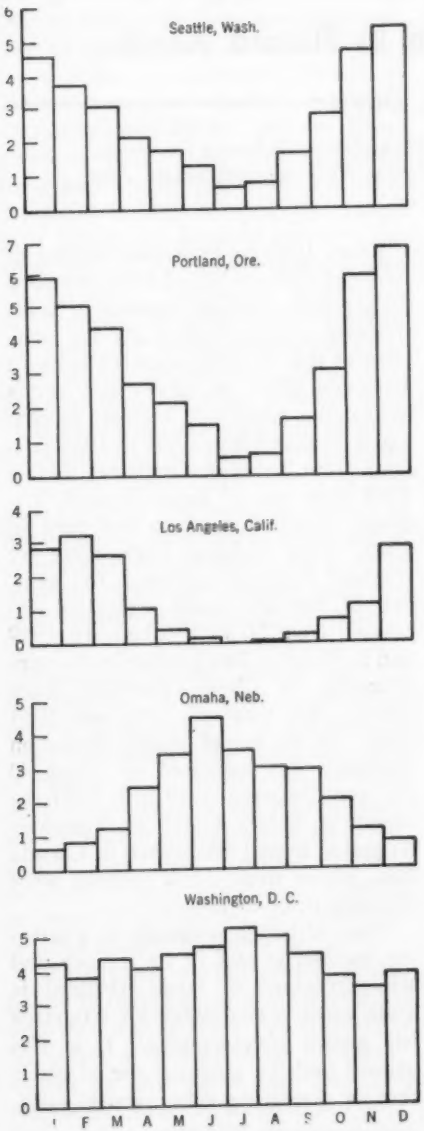

Fig. 7. Monthly Rainfall Distribution

Monthly rainfall is shown (in inches) for typical West Coast, Great Plains, and East Coast cities, for periods of record averaging 75 years.

strained by a better understanding of the many limitations which exist.

First, cloud seeding is not a cure for drought. It is not possible to make rain fall whenever and wherever it is desired, but rather to affect favorable weather conditions when and where they occur naturally.

Second, cloud seeding is not a substitute for water storage and irrigation. Indeed, it would seem to make these factors more important, for to exploit fully any additional precipitation obtained, it must be possible to store it when and where it falls and transport it to where it is needed, when it is wanted.

Third, the average increase obtainable under the most favorable circumstances appears to be of about 10–15 per cent, rather than the 50–100 per cent that was being estimated by some a few years ago. These amounts may be increased slightly by improved engineering practices and, modest as they are, may nevertheless be of considerable importance in a wide variety of circumstances. The actual economic benefit in each particular case must be determined on its own merits.

In April, a conference on the scientific aspects of weather modification was held at Tucson, Ariz., at which most of the outstanding scientists in this field from all parts of the world were present. In summing up the meeting, an eminent scientist made a remark which bears repeating. He said that 5 years ago the big question at such meetings was: "Does cloud seeding work?" Now the question no longer is whether it works, but rather: "How well does it work?" Great progress has been made and much more can be anticipated, as expanded programs of research and experimentation yield more thorough knowledge of the subject.

Future of Irrigation in Humid Areas

John R. Davis

A paper presented on May 8, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by John R. Davis, Asst. Prof. of Agricultural Eng., Purdue Univ., Lafayette, Ind.

THE greatest single use of water in the United States today is irrigation—75–100 bil gal per day, or about half of the fresh water used annually (*1*). Water use for irrigation is not distributed uniformly throughout the country, however; the 1950 census of agriculture states that 94.1 per cent of the irrigated land is in the 17 western states, and 5.3 per cent in Arkansas, Louisiana, and Florida. The remaining 28 states contain 0.6 per cent of the irrigated land and, if the above figures are correct, irrigation in those 28 states uses about 0.3 per cent of the water used annually in the entire country—hardly a formidable figure.

The use of water for irrigation in the humid United States is dynamic, however, and is increasing at a rate as rapid as that for other major water uses. Very little irrigation was practiced in humid areas before World War II except on truck and vegetable farms and by the exceptionally progressive farmer who realized its potential. The development of lightweight aluminum pipe and quick couplers in 1945 reduced irrigation labor costs and demonstrated that irrigation equipment was practical and could be adapted to many soils and crops. Research at experiment stations indicated the magnitude of the benefits that might be derived from irrigation, and, because farm prices were at a favorable level, the use of irrigation increased rapidly.

From 1940 to 1950, the number of irrigated farms in humid areas increased 75 per cent, and the number of acres irrigated increased about 283 per cent; most of this increase occurred between 1946 and 1950. A survey in Virginia indicated a seven-fold increase in irrigated farmland from 1949 to 1954 (*2*). Data from Tennessee indicates that in 1954 there was 21 times as much irrigated farmland as there had been in 1949. Even in Iowa, where there are frequent drainage problems, the number of farmers using irrigation increased from 76 to 136 between 1949 and 1954 (*3*). The number of farmers irrigating in Illinois increased from 139 to 266 between 1951 and 1954 (*4*). In all humid states, irrigation on farms has increased by about 70 per cent between 1949 and 1954, as shown in Tables 1 and 2. Sprinkler irrigation is well established in Canada also, where some 3,500 systems were installed prior to 1951 (*5*).

Thus, although irrigation as a farming method is still in its infancy and the percentage of lands irrigated is quite small, water usage for irrigation has grown phenomenally. It is this growth and the potential use of water that is disturbing other water users.

Benefits of Irrigation

To reconcile the use of water in a supposedly humid area and to explain

the growth of irrigation, one needs only to look at the countless data available on the response of crops to additional water. Irrigation in Georgia in 1953, for example, resulted in net increases of $399.50 per acre for sweet potatoes, $133.50 per acre for tomatoes, and $62.00 per acre for corn. Irrigation in Missouri in 1953 resulted in a $32.10 net increase per acre for corn and a $6.80 net increase per acre for soybeans. Tennessee reported a net increase of $102.36 on irrigated pastures, and Virginia reported a net increase of $282.00 per acre on irrigated tobacco. In 1955, a record corn yield of 300 bu per acre was attained in Mississippi, due partly to irrigation.

In some areas, other uses of an irrigation system are becoming almost as important as the ordinary supplying of additional moisture during the growing season. Sprinkler systems used for frost protection in Michigan, Wisconsin, and the Pacific Northwest have had amazing success. Experience with strawberries in Michigan showed a possible gross profit of $1,500 per acre when irrigation was used for frost protection (*6*). Another benefit is the efficient application of soluble fertilizers through sprinkler systems. Irrigation can also facilitate seedling emergence, seed germination, selection of better crop varieties, and reduction of wind erosion of bare soils.

The greatest overall benefit of irrigation in humid areas is not a result of irrigation alone, but a combination of irrigation with such crop production factors as new plant varieties, plant population, nutrient balance and fertilizers, incorporation of organic matter and soil tillage, and insect and disease control. Wise farmers have found that during the growing season it is rainfall, and not sprinkler irrigation, which is the supplemental source of water. Irrigation is thus an integral part of the agricultural production process—a production tool that eliminates the hazard of erratic and unpredictable rainfall, allows greater use of soil and other crop production factors, and enables the farmer to produce consistently at those levels which are most profitable.

Growth of Irrigation

Agencies of many states have attempted to predict the expansion of irrigation in the future, but most of these agencies will agree that present prediction figures are open to question. Agronomists at Purdue University estimate a potential of 2,000,000 acres of irrigable lands in Indiana, but the rate of growth needed to reach this potential remains undetermined. If the 1949–54 rate of expansion of 300 per cent is used to extrapolate into the future, it appears that irrigated lands in humid areas will have increased twelvefold by 1975. In Indiana this would result in a total of about 360,000 acres irrigated. Because some of the potentially productive areas are already partially irrigated and because some "wet" years are anticipated, practical estimates reduce this figure to 60,000–100,000 acres by 1975. For the entire country, tentative estimates propose that by that year sprinkler-irrigated acreage will have increased from 1.3 million acres in 1955 to 4.2 million acres. This represents a total water use of 16.85 bil gal per day for sprinkler irrigation in 1975 (*7*).

Farm prices will have a considerable effect on the growth of irrigation. If farm prices are high, irrigation may grow rather rapidly; if prices are low, the growth of irrigation may be slower (*2*). On the other hand, irrigation increases the efficiency of pro-

TABLE 1

*Irrigated Acreage and Number of Farms Using Irrigation, 1949 and 1954**

State	Farms Reporting Irrigation		Acres Irrigated	
	1954	1949	1954	1949
Alabama	452	34	16,658	367
Arizona	6,679	7,822	1,168,165	963,560
Arkansas	6,213	3,060	857,930	422,107
California	84,476	90,755	7,048,792	6,438,324
Colorado	23,354	27,121	2,202,921	2,872,348
Connecticut	405	280	11,975	8,088
Delaware	81	10	5,553	404
Florida	5,799	6,075	428,392	365,421
Georgia	1,268	139	23,973	3,161
Idaho	28,204	29,413	2,324,120	2,137,237
Illinois	266	139	6,789	1,510
Indiana	443	164	11,749	5,339
Iowa	136	76	2,396	1,386
Kansas	2,736	1,166	331,551	138,686
Kentucky	1,226	67	13,434	485
Louisiana	6,898	7,438	706,627	576,775
Maine	87	123	1,097	2,299
Maryland	235	30	8,344	697
Massachusetts	1,366	1,053	22,683	18,507
Michigan	1,408	995	23,473	13,901
Minnesota	347	274	9,207	4,235
Mississippi	1,703	44	132,490	5,086
Missouri	752	142	32,998	2,089
Montana	13,114	13,457	1,890,722	1,716,792
Nebraska	12,503	9,680	1,171,623	876,259
Nevada	2,509	2,819	567,069	727,498
New Hampshire	61	51	942	622
New Jersey	1,775	1,033	58,912	28,117
New Mexico	11,686	12,691	645,730	655,287
New York	1,675	888	59,024	19,248
North Carolina	2,704	96	25,423	2,083
North Dakota	413	304	44,540	35,294
Ohio	847	458	15,679	5,706
Oklahoma	1,621	466	107,981	34,071
Oregon	19,827	17,663	1,490,397	1,306,810
Pennsylvania	883	287	17,950	7,251
Rhode Island	43	52	1,009	1,631
South Carolina	748	84	22,983	6,408
South Dakota	923	807	90,471	78,069
Tennessee	1,094	35	22,548	1,012
Texas	26,318	21,427	4,706,017	3,131,534
Utah	19,406	21,126	1,072,682	1,137,995
Vermont	55	22	689	303
Virginia	763	71	21,805	2,817
Washington	18,727	16,928	777,834	589,035
West Virginia	62	9	1,381	40
Wisconsin	545	354	18,199	9,781
Wyoming	7,129	7,831	1,261,132	1,431,767

* Data are from US preliminary census.

duction of most crops so that production costs per unit of produce are less. Up to a certain point, therefore, lowering farm prices may tend to stimulate irrigation slightly. Administration programs such as a "soil bank" or "tree bank" would probably stimulate a growth in irrigation because they will indirectly encourage farmers to produce more from their allotted croplands. Deficiencies in rainfall, the extent of droughty soils, proposed water rights legislation, development of water supplies, development of food-processing methods, and availability of markets will all influence irrigation.

Because irrigation farming is still new, then, and because of the many influencing factors, the potential growth of irrigation is difficult to predict. Only by analyzing the irrigation potential on a small-area basis, such as by counties or small drainage basins, can one arrive at an accurate forecast.

Present Irrigation

Most humid states have prepared or are preparing data on the use of water for irrigation. These data, based primarily on the use of available climatological data, have enabled investigators to determine daily, monthly, and seasonal use of water (*8*). The probable frequency of drought occurrence and the probability and magnitude of annual and monthly soil moisture deficiencies can then be calculated. Tables 3 and 4 are examples of such calculations.

Although appreciable soil moisture deficiencies exist during almost every year, irrigation has not yet progressed to the extent that it represents a competitive use of water. In support of this, very few irrigators in the humid areas have been denied water for irrigation by the courts, even though the right of the farmer to use water for irrigation has not been fully clarified

TABLE 2

Summary of US Census Data on Irrigated Lands

Item	1949	1954	Increases, 1949–54
Acres Irrigated			
17 western states	24,270,566	26,901,747	+2,631,181
31 humid-area states	1,516,876	2,582,312	+1,065,436
Humid-area states except Arkansas, Mississippi, and Louisiana	512,908	885,265	+372,357
Number of Farms Using Irrigation			
17 western states	281,476	279,625	−1,851
31 humid-area states	23,583	40,340	+16,757
Average Acres Irrigated per Farm			
17 western states	86	96	+10
31 humid-area states	64	64	0

by the courts in most states (*11*). Water use for irrigation in Ohio, for example, is almost negligible, as shown in Table 5 (*12*). A preliminary report on one river basin to the Indiana Water Resources Study Committee indicates an irrigation use of about 2.5 mgd during the 1954 growing season, whereas all other uses totaled about 23.6 mgd average use..

Unlike the West, where a large part of the economy is predicated on the use of water for irrigation, the Midwest and the East, are not yet faced with water shortage problems in which irrigation water use is involved. Thus, in many instances, the present needs of water for irrigation have been overemphasized and are in no way creating a critical water demand situation. Only in such localized areas as on Long Island, N.Y., has irrigation had a known deleterious effect on water supplies.

TABLE 3

*Frequency of Moisture Deficiency at Minneapolis, Minn.**

Recurrence Interval *years*	Annual Moisture Deficiency—*in.*		
	Alfalfa	Corn	Small Grains
2	3.5	2.4	0
3	4.8	3.5	0.9
5	6.6	4.5	2.1
10	8.7	5.8	3.6
20	10.8	6.7	5.0

* Based on 62-year climatological record, with soil having 5 in. of available moisture in the root zone at field capacity. Data are from Reference 9.

Potential Use for Irrigation

The water requirements for irrigation agriculture, in inches of water per acre, will essentially remain the same in future years. Furthermore, improved irrigation efficiencies and adaptation of more desirable crops may lower the water requirements of crops slightly. As the acreage of irrigated land increases, however, the total water use for irrigation will increase. For example, applying 1 in. of water on 1 acre requires about 30,000 gal. If the average water deficiency in a particular area is 8 in. per growing season and the number of acres irrigated increases by 1,000 acres, the increase in water use will be about 240 mil gal. If all of this water is applied during the period July–August, the increase in average daily use would be about 4 mgd.

The problem of estimating potential water use for irrigation, therefore, revolves around the estimated increase in the acreage that will be irrigated. As previously mentioned, these forecasts are difficult to make and may be quite unreliable, but it is still possible to arrive at estimates of increased water use by irrigation based on a given increase in the number of acres irrigated. Studies suggest that, in Kansas, increase in water use for the next 20 years would be as follows: for domestic purposes, 72 to 85 mgd; for municipal purposes, 70 to 110 mgd; for irrigation purposes, 480 to 1,140 mgd; and for industrial purposes 30 to 60 mgd (*13*).

A study recently completed at Purdue University (*14*) on water deficiencies and irrigation water requirements for a 47,000-acre area in Indiana is summarized in Tables 6 and 7. These data show mean soil moisture deficiencies of 7.5 in. per growing season for tame hay, 6.56 in. for corn, and 6.04 in. for soybeans, representing a mean volume of water of 4,298 mil gal required to make up the deficit. There is a possibility that over 9,000 mil gal would be required during 2 years out

TABLE 4

Expected Frequency of Dry Periods in Alabama

Place	Mar.–May	Jun.–Aug.	Sep.–Nov.
Number of 4-Week Dry Periods in the Next 100 Years*			
Cullman, Ala.	35	44	96
Clanton, Ala.	53	27	107
Robertsdale, Ala.	49	16	96
Number of 3-Week Dry Periods in the Next 100 Years*			
Cullman, Ala.	106	102	171
Clanton, Ala.	110	87	181
Robertsdale, Ala.	102	35	170

* The 3- and 4-week periods are for consecutive weeks with less than 1 in. of accumulated rainfall.

of 100. The average daily water requirement for 60 days would then be about 72 mgd for the mean use and 173 mgd for the maximum use. This is the type of probability data that should be used to study irrigation water requirements; average quantities, although they are of value, do not describe the conditions existing in drought years. Data in Table 7 can be coordinated with stream flow duration curves and is of distinct value in planning reservoir storage releases and water use regulations.

Estimated water deficiencies for most of the humid-area states are given in Table 8. The water deficiencies shown, however, are only estimates of the average water deficit, and in a hot dry year the water deficiency could well be double the figures given. Assuming that 30,000 gal per acre is required to make up 1 in. of water deficiency, the total volume of water required to make up the mean deficit can be estimated. Present-day use can thus be approximated, and, depending on the increase in irrigated acreage, future use can be estimated. For example, the irrigated acreage in 1955 in Indiana was about 30,000 acres, requiring about 7.2 bil gal annually. If the irrigated acreage were to increase to 80,000 acres in 1975, the water use would be about 19.2 bil gal annually—an increase in water use of 12 bil gal per year. The limitations in the use of these data are: [1] the deficiencies given in Table 8 are average annual deficiencies and do not indicate water requirements in extremely dry years; and [2] the water requirement of crops grown on sandy soils is greater than that of crops grown on clay soils. Thus, water deficiencies in local state areas may be higher or lower than the average for the state. Estimating the number of acres that will be irrigated in any particular area depends on so many factors that the rate of increase over a specified period of time can be determined only by an educated guess. Thorough studies of crops and soils, present irrigation practices, present and potential water supplies, availability of irrigation equipment, the buying power of farmers, and long-range weather forecasting will be necessary before any accurate predictions can be made.

TABLE 5

Daily Water Requirements in Ohio

Type of User	Water Used—*mgd*
Rural	
Livestock	48
Domestic	60
Irrigation	1
Municipal	800
Industrial	8,500

Management Problems

Will there be enough water to go around? That is the question that is

TABLE 6

*Estimated Soil Moisture Deficiencies for Three Crops in Knox County, Ind., 1914–1954**

Annual Moisture Deficiency—*in.*	Tame Hay		Corn		Soybeans	
	Frequency of Occurrence					
	Number of Years	Percentage of Total Years	Number of Years	Percentage of Total Years	Number of Years	Percentage of Total Years
0.9– 1.4	3	7.3	5	12.2	4	9.8
1.5– 2.9	2	4.9	3	7.3	4	9.8
3.0– 4.4	4	9.8	2	4.9	6	14.6
4.5– 5.9	6	14.6	8	19.5	8	19.5
6.0– 7.4	5	12.2	9	22.0	7	17.1
7.5– 8.9	7	17.1	4	9.8	4	9.8
9.0–10.4	5	12.2	2	4.9	3	7.3
10.5–11.9	2	4.9	6	14.6	4	9.8
12.0–13.4	6	14.6	1	2.4	0	
13.5–14.9	0		0		0	
15.0–16.4	0		1	2.4	1	2.4
16.5–17.9	0		0		0	
18.0–19.4	1	2.4	0		0	
Maximum Deficiency—*in.*	18.09		16.31		15.81	
Minimum Deficiency—*in.*	+0.60		+0.73		+0.84	
Mean Deficiency—*in.*	7.50		6.56		6.04	

* Data are for a selected area of 47,000 acres. Data are from Reference 14.

inevitably raised when irrigation is mentioned. To find the answer, a few facts about irrigation as a water use should be considered.

First, water that is applied to soil through irrigation systems is totally consumed by evaporation and transpiration. Irrigation water does not return to ground water. None of it should run back into streams, and none of it is returned to land masses in the form of precipitation. Irrigation, therefore, is a consumptive use of water, unlike municipal use and some industrial uses which may make a return of over 90 per cent.

Secondly, the increase in the demand for irrigation water is directly related to the decrease in available water supplies; that is—as hot dry weather lowers water levels and decreases stream flows, the water demand for irrigation increases.

Thirdly, the feasibility of using water for irrigation is subject to the quality of the water, although not to the same degree that municipal or industrial uses are. Generally, although plant tolerance must be considered, water temperature and the degree of pollution have little effect on the suitability of water for irrigation.

Most people feel that there *will* be enough water for everyone, provided the job is handled in the right way. Unified coordination of all water interests to stimulate wise use and development of water resources and to obtain most efficient usages of available water is necessary.

Some of the conditions responsible for the failure of water supplies to meet requirements, are inadequate design and planning of water-consuming processing equipment, water wastage, selection of sites for development without adequate evaluation of availability of water for existing or predicted future requirements, and failure to provide for equalization of surface water runoff (*16*). To avoid these conditions, every effort should be made to improve water supply systems, to encourage additional water storage in watersheds, to coordinate surface and ground water resources, to survey and study surface water and underground suppies and uses, and to provide a flexible method of regulation of water use wherever necessary.

TABLE 7

*Estimated Quantity of Water Required to Make up Deficit for Growing Seasons of Three Crops in Knox County, Ind., 1914–1954**

Estimated Quantity Required to Make Up Deficit for Growing Season—*mil gal*	Number of Years Required	Percentage of Total Years Required
0– 999	4	9.8
1,000–1,999	4	9.8
2,000–2,999	3	7.3
3,000–3,999	9	22.0
4,000–4,999	6	12.2
5,000–5,999	5	12.2
6,000–6,999	4	9.8
7,000–7,999	4	9.8
8,000–8,999	1	2.4
9,000 or more	1	2.4
Maximum quantity required—*mil gal*	10,407	
Minimum quantity required—*mil gal*	9	
Mean quantity required—*mil gal*	4,298	

* Data are for quantity of water needed to make up difference between potential evapotranspiration and effective moisture. The crops were tame hay, corn, and soybeans and the land area was approximately 47,000 acres in size. Data are from Reference 14.

Water supply problems will be unique to certain areas. In a report on ground water resources of the Eighth Federal Reserve District (*17*), which includes parts of the states of Illinois, Indiana, Kentucky, Missouri, Tennessee, Arkansas, and Mississippi, it is stated: "The physical quantity of water appears sufficient for needs over many decades in major district cities and to meet further farm irrigation demands. It is difficult to foresee any shortages within the next generation, provided facilities are increased and abuses lessened." On the other hand, statements like "It seems certain that irrigational use of water will increase in the future and aggravate the municipal and industrial water shortages" (in Virginia) (*18*) indicate that intelligent water use regulation or development of better supplies is necessary already.

TABLE 8

*Average Annual Rainfall Deficiency in Eastern United States**

State	Average Deficiency—*in.*
Alabama	10
Arkansas	12
Florida	6
Georgia	10
Illinois	9
Indiana	8
Kentucky	9
Louisiana	8
Michigan	8
Mississippi	11
Missouri	6
New Hampshire	6
New York	4
North Carolina	8
Ohio	8
Pennsylvania	4
South Carolina	10
Tennessee	10
Virginia	6
West Virginia	6
Wisconsin	6

* Data are from Reference 15.

Conclusion

Irrigation should not be treated as an unnecessary evil, nor as a minor or temporary use of water. It has already prompted water rights legislation, studies of water resources, and development of water supplies.

Irrigation is a crop production tool which can be used to maintain the present standard of living in future years. The potential water requirements of irrigation should be planned for now. If efforts are made in this direction, few restrictions will be necessary and there should be enough water for everyone.

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Relative Economic Returns From Industrial and Agricultural Water Uses

Sheppard T. Powell

A contribution to the Journal by Sheppard T. Powell, Cons. Engr., Baltimore, Md.

THE availability of water for manufacturing and other industrial purposes depends on its allocation among the various competing needs—industrial, domestic, and agricultural. Domestic requirements for the direct support of life must be given first priority. After these are satisfied, additional water resources, where available, can be apportioned between agriculture and industry. A complete discussion of the relative benefits of allocating scarce water supplies for the two conflicting purposes is not in order here; a comprehensive study would involve complex questions of legal, political, and sociological influences. It is pertinent, however, to mention briefly certain economic aspects of water use in industry as opposed to its use in agriculture.

Agricultural Uses

It has been noted that municipal and industrial uses of water are largely nonconsumptive. This means that most of the water used in industry can be reused repeatedly, and very often is. The opposite is true for agricultural uses. Almost all irrigation water is used only once, because it becomes a part of the crop or is lost to the atmosphere by evapotranspiration.

The use of water for irrigation is extremely uneconomical when compared to industrial uses. The value of crops grown on irrigated lands in the western United States in 1947 was 2.4 billion dollars (*1*). These lands required some 25 trillion gallons of water during the year, which amounts to less than 10 cents worth of crops for every thousand gallons of irrigation water.

It has been estimated that annual water needs on a large irrigation project in the western United States are 3.68 acre-ft of water per acre of land. The crops from this project consist mainly of wheat, sugar beets, and beans. The gross annual crop return for this project was estimated at $90 per irrigated acre (*2*). Thus, the value of crops produced amounted to 7½ cents per thousand gallons of water used.

Manufacturing Uses

Water used for manufacturing in the United States in 1953 amounted to 11.4 trillion gallons. The value added by manufacture of goods in the United States during that year amounted to 121.7 billion dollars, or an average of about $11.70 per thousand gallons of water used (*3*). The ratio of value added by manufacturing to value added by agriculture was thus about 140 to 1 for a given quantity of water used. Although this ratio may vary upward or downward when comparing a given agricultural crop with a specific indus-

trial product, it is a strong indication of the economic advantage of the utilization of scarce water resource for manufacturing in preference to agricultural pursuits.

Discussion

Because industrial utilization of water is largely nonconsumptive, whereas water used in irrigation is, for the most part, consumed, those responsible for establishing a country's water use policy should study carefully the relative benefits to be gained by allocating scarce water resources to various uses. It is clear that water must be relatively abundant and cheap to allow its profitable use for irrigation.

In many arid lands, developing water in sufficient volume for irrigation projects necessary for crop growth is unrealistic because of excessive cost. Commenting on this situation in the United States, L. A. Miller (*4*) stated:

> There is no discernible way by which the arid states can acquire more water than they already have by the ordination of nature. How, then, will they choose to use it? By urging arid lands to produce, at great expense, new crop surpluses? Or will they, in their own interest, decide to use it to develop their great industrial opportunities?
>
> The Paley Commission (*5*) showed how irrigation uses up water supplies, and says: 'In 1950, the 26 million acres of irrigated land (98 per cent in the western states) consumed about 50 per cent of all the fresh water withdrawn from the lakes, rivers, and streams in the entire United States. Most of this irrigation water is finally lost by evaporation, and so is not available for further use. It is believed that irrigation accounts for over 80 per cent of the consumptive depletion of all water uses.'

This observation on the use of limited water resources for irrigation, instead of for the more lucrative industrial requirements, is most timely. Although they concern the United States, the comments are applicable to many other areas of the world. The quantities of water necessary for crop growth would in many cases support miscellaneous industries with financial return greatly in excess of the value of crops. This, in turn, would permit the importation of essential food supplies from remote areas more suited to agriculture.

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Nebraska Water Legislation and Associated Administrative Problems

Dan S. Jones

A paper presented on Apr. 13, 1956, at the Nebraska Section Meeting, Lincoln, Neb., by Dan S. Jones, Chief, Bureau of Irrigation, Water Power and Drainage, Dept. of Roads and Irrigation, Lincoln, Neb.

IN *Selected Problems in Western Water Law* (*1*), Wells Hutchins states that "the western law of water rights embraces two diametrically opposite principles—the common-law doctrine of riparian rights, and the statutory doctrine of prior appropriation. Under the riparian doctrine, the owner of land contiguous to a stream has certain rights in the flow of water, by virtue of such land ownership. Under the appropriation doctrine, the first user of the water acquires a priority right to continue the use, and contiguity of land to the watercourse is not a factor."

Background

The doctrine of prior appropriation exists in all seventeen of the western states; in some of them, however, the riparian doctrine has been recognized, while in others, including Colorado, Wyoming, and New Mexico, the riparian doctrine has been specifically repudiated and only the appropriative doctrine exists. Nebraska is one of the states in which the riparian doctrine was not specifically repudiated but it has been so restricted by court decisions that it has virtually given way to the appropriative doctrine. The states lying east of Nebraska, North Dakota, Kansas, and Oklahoma still use the riparian-rights doctrine.

The doctrine of prior appropriation rests upon the theory that the water of all natural streams is the property of the public and that the common-law doctrine of riparian rights is unsuited to semi-arid conditions and never was applicable in such states as Colorado and the other arid and semi-arid states. Quite naturally, because it is in a zone ranging from semi-arid to sub-humid, Nebraska would not adopt the doctrine of prior appropriation in toto. Most of the Nebraska decisions have restricted the operation of the riparian doctrine, by limiting payments to cover only those damages the riparian owner could prove to have resulted from the invasion of his right. In this way, the riparian doctrine has given way to the appropriative doctrine.

Before Nebraska became a state, the streams in the territory were used for domestic, irrigation, and milling purposes. The first constitution, however, made no provision for water rights. The common law of England was adopted in 1867 and remained the only semblance of a water law until 20 years later, when the law relating to internal improvements gave canal companies the power of eminent domain and the right to issue bonds.

The 1889 legislature enacted the so-called St. Raynor Law, which provided that rights to the use of the waters of natural streams could be obtained by appropriation. It provided a means for initiating a water appropriation but it made no provision for its adjudica-

tion or for the administration of water rights. The use of water for irrigation expanded rapidly in the early 1890's, and the 1895 legislature adopted a comprehensive water code based entirely upon the doctrine of prior appropriation. It was patterned after Wyoming's water law, which had been in effect for several years and had proved generally satisfactory.

The 1895 act established the State Board of Irrigation and provided for the appointment of a state engineer as the chief administrative official. The board was given jurisdiction over all matters pertaining to water rights for irrigation, power, or other useful purposes, and the law applied strictly to the waters of the natural streams. It made no mention of rights applying to the use of ground water, however, and this is still true of the laws that are in effect today.

The name of the administrative agency has been changed several times and the water law has been amended occasionally, but the functions of the agency and the fundamentals of the law have remained basically the same during the past 61 years. The law has been tested and interpreted by the courts, and a healthy irrigated agriculture has resulted from adequate water laws which back up the necessary investments.

Although the 1895 act provided that the right to use water for domestic purposes takes precedence over the right to use it for agricultural purposes, and agricultural use takes precedence over manufacturing uses, it is evident that the use of water for irrigation purposes was uppermost in the minds of the framers of the act. This is evidenced by the following sections of the statutes, quoted as they appear in the 1943 reissue of the revised statutes:

Section 46–201: Water for the purposes of irrigation in the state of Nebraska is hereby declared to be a natural want.

Section 46–245: Any canal constructed for the purposes of developing water power, or any other useful purpose, and from which water can be taken for irrigation is hereby declared to be an "irrigation canal" and all laws relating to irrigation canals shall be deemed applicable thereto.

Nowhere in the water law is any other water use emphasized as is irrigation.

In establishing the preferential uses of water, the early enactments made no provision for the protection of prior appropriators for an inferior use, and it was not until the 1920 constitution was adopted that this lack was considered. Article XV of that constitution provides that, between those using water for the same purpose, priority of appropriation shall give the better right, but, when the waters of any natural stream are insufficient to supply all those desiring to use it, domestic users shall have a preference over those using it for irrigation, and those using it for irrigation shall have a preference over those using it for power purposes. No inferior right to the use of water shall be acquired by a superior right without just compensation to the inferior user, however. In other words, if a city seeks to use water for domestic purposes or an irrigator seeks water for irrigation purposes, and that water is being used by a power appropriator, the power appropriator must be compensated for any depletion of his supply.

A 1941 amendment to the Public Power and Irrigation District Act provided for the appointment of a court of water claims, composed of three district judges, to determine "just com-

pensation" in case the superior user was unable to negotiate a settlement with the power appropriators. Unfortunately, in the author's opinion, this provision has been repealed and at present, if the parties cannot agree, the general law relating to condemnation proceedings must be relied upon.

Present Provisions

Some of the other basic provisions of Nebraska law which are concerned here are the following:

1. The water of every natural stream is the property of the public, and the right to divert the unappropriated water for beneficial purposes shall never be denied.

2. A water appropriation can be initiated only by the filing of an application for a permit to appropriate water in the office of the Department of Roads and Irrigation. The priority of the appropriation dates from the day of filing, regardless of the date on which water use might have begun.

3. Water, if appropriated for irrigation, attaches to the land. If appropriated for power or for any other purpose, it attaches to the specific use and to the site for which it is granted. Neither the place of use nor the character of the use may be changed. When the use for which an appropriation is made ceases, the right ceases.

4. Water may be appropriated for storage in reservoirs, for useful purposes. Any water not needed for irrigation by direct diversion from the stream, regardless of priority, or for storage in senior reservoirs may be stored in such reservoirs.

Although many of the difficulties encountered by the pioneers in water administration no longer exist, many serious problems still remain to be solved. With the tremendous growth of irrigation in recent years in the eastern part of Nebraska, there is pioneering to do in setting up workable procedures and in educating the water users in conforming to regulation.

Bureau of Irrigation

The essential duties of the Bureau of Irrigation are twofold. Usage rights to water must be determined and recorded, and methods for administering those rights must be formulated.

The term "administer," as used here, involves the day-to-day allocation of water in streams when the supply is insufficient for all of those who desire to use it. For many years, the waters of the North Platte, South Platte, and Platte rivers and their tributaries, upstream from Kearney, have been appropriated to the extent that during each irrigation season it is necessary to regulate diversions according to priority. In that portion of the Platte Basin, the bureau has an effective and well organized staff of engineers and water commissioners which checks the numerous diversion structures daily, from May through September, regulating them as required. In this connection, the distribution of water from the federal reservoirs in Wyoming and Lake McConaughy, near Ogallala, is involved, and the natural flow and storage of water in the rivers are segregated by the use of complicated formulas, taking into account losses from evaporation, seepage, and other factors.

The recent irrigation development in the Republican River Basin through the construction of federal works has made strict administration necessary there. A staff is being built up as the development progresses to handle the work adequately.

Republican Basin

Two matters which have developed in the Republican Basin are worthy of mention here. One is the fact that a procedure has been developed to equalize appropriation priorities for the project lands extending along the river from Trenton Dam to Superior. It involves a pooling of the waters stored in the four completed federal reservoirs and in the one still to be constructed. In effect, it permits water stored in Harlan County Reservoir, near Alma, to be used on land near McCook by exchanging it for natural flow. The arrangement also permits the storing of water in the Swanson Reservoir at Trenton under the Harlan County Reservoir appropriation. The plan provides flexibility which should result in maximum efficiency in the use of the available water supply, and virtually insures a full supply to all of the project lands.

The other matter has to do with a phase of the operation of the Harlan County Reservoir. Under an operations procedure which was developed in 1952 by the US Army Corps of Engineers and operators of the reservoir, and generally concurred in by other federal and state representatives, it was agreed that, during the initial filling of the reservoir, certain minimum flows would be maintained in the Republican River at Superior, Neb., Concordia, Kan., and elsewhere for sewage dilution purposes. The author favors this type of operation, pending the completion of the irrigation projects, when all of the water will not be needed for irrigation on the lands for which it was appropriated.

The water supply of the Republican River, like other streams in the area, has been extremely deficient in the past 4 years. During much of the late summer months of these years the river was dry above Harlan County Reservoir and storage water was released to maintain the minimum flows. It was originally thought that any natural flow available in the river would be passed through the dam to the extent necessary for maintaining the minimum flows. The furnishing of free storage water to the municipalities for sewage dilution places these municipalities in a preferred status when compared to the irrigators who are served storage water for their lands through the works of the irrigation district. The irrigators are required to pay in advance for the storage water they receive under appropriations obtained according to law.

To complicate the situation further, numerous landowners along the river who have not been or cannot be served by the irrigation district have placed pumps in the river between Harlan County Dam and Superior, and they are using water for irrigation. Permits have been granted by the department to these landowners to pump natural flow from the river. These users are actually taking, free of charge, the storage water which is being released from the reservoir for dilution purposes at Superior and the towns along the river in Kansas, which also receive the water at no cost.

No way has yet been determined by which the right to divert the water can be denied the landowners, since the water which is running uncontrolled down the river is unappropriated and one of the fundamentals of Nebraska law is that the right to divert the *unappropriated* waters of the natural streams shall never be denied. Although the object is not to prevent farmers from irrigating, it does seem that they should pay the owner of the reservoir for storing and releasing the water. The use of pumps in the

streams necessitates the release of larger quantities of water from the reservoir to get the minimum amounts to Superior and below.

The author realizes that it is highly desirable to maintain certain minimum flows in the public streams, not only for sewage dilution but for the benefit of fish and wildlife and other worthwhile reasons. Although appropriations have been perfected for water for fish and wildlife, water so appropriated must be stored in reservoirs or otherwise diverted from the stream. The author doubts that an appropriation for water to run uncontrolled in a stream can be acquired under Nebraska law.

According to Wells Hutchins (*1*), "the rule is often stated that to constitute a valid appropriation of water there must be an actual diversion from the natural source of supply. It is so stated in one form or another in a number of decisions. In actual practice it is unquestionably the case that the vast majority of appropriative rights are based upon diversions of water from the stream channels into canals or other conduits, or upon retentions of the water stored in channel reservoirs to be diverted subsequently as needed." The author feels that this statement accurately characterizes the situation in Nebraska.

With further reference to the release of water from reservoirs for sewage dilution in the Republican Basin, the terms of the Republican River Compact may be the determining factor when irrigation is fully developed. The compact allocations of water among the basin states are for beneficial consumptive use and it is intended that other uses will be incidental to such use.

Another water use which falls in somewhat the same category as the one just discussed is the use of water for watering livestock. This use would surely fall in the classification of domestic use for which appropriations may be made. Applications for permits to store water for stock purposes have been granted in Nebraska and the permits are being used. There are no appropriations on record for water to run uncontrolled down a stream for stock purposes. Landowners along streams frequently complain that upstream irrigation appropriators are depriving them of water for their stock. During the last two summers such complaints have been numerous.

Upon receipt of such a complaint, the Bureau of Irrigation advises the water users who may be responsible for it and suggests that, if possible, they let enough water pass to take care of the stock requirements. That is as far as the bureau can go, and it advises the complainant to seek help in the courts. The Nebraska statutes place no responsibility whatever on a water appropriator to maintain a flow of water in the stream below his diversion works and, further, the statutes authorize the department to recognize only the water rights that have been acquired and made of record by law.

One of the bureau's basic administrative practices is to require that, of those appropriators entitled to water, the one who is farthest downstream shall take all of the water in the stream before an upstream junior will be denied water for his benefit. The US Supreme Court decision which allocates the waters of the North Platte River among the states of Colorado, Wyoming, and Nebraska, requires that no water shall be wasted at the Tri-State Dam, just below the Wyoming-Nebraska state line, which is the lowest point on the river to which the upper states are obligated to furnish water.

Power and Irrigation

Another administrative matter which affects many people and which was the subject of much publicity last summer is in connection with the regulation of water use in the Loup River Basin. The problem results from the conflict between the uses of water for power and for irrigation. In 1932, the Loup River Public Power District filed an application for water for power purposes. Prior to that time very little of the basin's waters had been used for irrigation. Early in 1933, the two irrigation districts on the North and Middle Loup Rivers filed applications for water for irrigation. Certain compromises were made by the three parties, and the irrigation interests, by stipulation, were granted prior appropriations.

Except for two very short periods soon after the projects were completed, the power district did not demand that appropriations be administered for the benefit of its prior appropriation. During the last 20 years, with the development of economical pumps and distribution systems, some 400 or 500 irrigation pumps have been installed in the basin, each with a capacity of more than 1 cfs.

A year ago, the Loup River Public Power District officially demanded that the department administer the water of the basin for the protection of its power appropriation. It was necessary to serve notice on all of the appropriators with priorities later than 1932 that, after a specified date, they would be denied water unless they could show that they had agreements with the power district to compensate for the power lost because of depletions for which they were responsible.

The notices came as a shock to the irrigators. Although all permits granted after the approval of the power permit called particular attention to the requirement that power interference must be compensated for, little or no attention had been paid to the warning because for so many years the power district had not objected to diversions for irrigation without compensation. After several weeks of discussion, during which time the administration of the river was deferred, a form of contract was agreed upon for use during the 1955 season. The agreement provided for a deposit in escrow by the irrigator equal to $1 for each acre-foot which the irrigator estimated he would use during the summer as a guarantee of payment for the water used when the just value has been determined.

It is anticipated that the value arrived at in the current negotiations between the power district and the US Bureau of Reclamation for payment for power interference will serve as a yardstick for settlement between the individual irrigators and the district involved.

Reference

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Recommended Action Against Effects of Severe Droughts in Kansas

Dwight F. Metzler

A paper presented on Apr. 5, 1956, at the Kansas Section Meeting, Topeka, Kan., by Dwight F. Metzler, Chief Engr. and Dir. of Div. of Sanitation, Kansas State Board of Health, Lawrence, Kan.

THE competition for water is growing. Because of deficient rainfall and increased agricultural, municipal, and industrial use, this competition is greater than it ever was before. H. A. Thomas, a Harvard University professor, in a recent discussion of studies to determine the amount of radioactive fallout present over a period of time, including Russian and American nuclear tests, reported that federal law would permit an individual to possess 0.01 millicurie of radioactive material without a permit. At times, Thomas continued, 1 liter of rainwater caught in Harvard Yard contained more than this limited amount of radioactive material. No individual, therefore, could have collected a quart of this water without a permit. This shows that some of the water in the atmosphere is used to dilute the products of nuclear explosions and wastes from atomic operations, suggesting that the next half century will see many additional demands develop upon this country's available fresh-water supply.

Causes of Water Shortages

To determine the extents and causes of water shortages, the quantity of available fresh water must be known. This requires the measurement of atmospheric moisture, rainfall, stream flow, ground water, soil moisture, and the amount of water stored in reservoirs and lakes. In Kansas, the available water supply is the rainfall within the state plus an average 1,700,000 acre-ft of inflow. Of this total supply, 89–98 per cent, from east to west, is lost to further use through evapotranspiration. As might be guessed, this includes all evaporation plus transpiration from all vegetation. Thus, 2–11 per cent is left for surface runoff and ground water outflow, depending upon the part of the state being considered.

Maldistribution

Maldistribution must be blamed for part of the water shortages in Kansas. This is evident when one considers that the average annual rainfall varies from 16 in. to more than 40 in. per year across the state of Kansas, from west to east.

Underdevelopment

Underdevelopment of water resource facilities also contributes to Kansas water shortages. This is evident when one considers that an average of over 10,000,000 acre-ft of water per year

flows from the state unused. In 1951 this amount was 42,000,000 acre-ft. The effect of inadequate development is particularly noticeable in city water supplies. During a 3½-year period beginning in 1952, 62 cities had to provide emergency water supplies, and 175 were short of water. The extreme distress occurred in eastern Kansas, where ground water is limited and cities depend upon streams and impoundments for surface water. Some of the reservoirs proved to be inadequate and cities were forced to start hauling or to take other emergency procedures.

A typical example of underdevelopment occurred in 1950, when Olathe, Kan., began to consider an expansion of the municipal water works. The inadequacy of the source of supply was evident, but, against sound engineering recommendations and because Olathe could not finance both a new impoundment and a treatment plant, the city proceeded to build a new water treatment plant only. In April 1954 the old reservoirs were dry and the city undertook another development, almost as expensive as the first, which was to build a reservoir. During its construction, water was brought in by rail from Kansas City. The fortunate occurrence of a small and intense rain storm on the watershed saved the city from the heavy expense of continued hauling.

Shortages caused by underdevelopment and other factors have caused a deterioration in the municipal water service which would have been impossible a decade ago. Water has been hauled by tank car and gasoline transport. It has been pumped through a refined-oil products pipeline when the line was not being used to carry gasoline or fuel oil, and in a few small towns water service was attempted for only a few hours each day during the worst of the drought. This compares with the experience in Hong Kong, a city of 3,200,000, where even the finest establishments in the city obtain water only 4 hr a day.

Weather Cycles

Weather cycles have combined with the economic tides to contribute to water shortages. The relatively wet years of the 1940's seemed to indicate no future problems; these, and the material shortages of World War II which affected construction, resulted in water deficiencies and inadequate facilities to handle the warmer and drier years that followed. The depression days of the 1930's plus the material shortages of the 1940's caused a period of longer than 15 years in which capital improvements were not provided.

Population Growth

Many cities, already faced with shortages because of inadequacies of physical facilities, encountered new demands from population growth, expanded industrial usage, and increased per capita water consumption. In spite of water conservation measures, the ratio of peak to average daily consumption increased markedly. Much of this was undoubtedly caused by air-conditioning demands, but domestic and industrial uses have sufficiently increased the average daily demand to make the added load disastrous in some cities. Fortunately, industries, as well as individuals, have learned much about conserving water. Two refineries at El Dorado, for example, reduced their water consumption from

129 to 60 and from 160 to 62 gal per barrel of crude oil processed. These values compare with average water use of 770 gal per barrel of crude oil in the refineries in the Ohio River Valley.

Pollution

Even though fairly well under control, water pollution still contributes to water shortages for farmers and industries as well as for cities. This is particularly true of chloride pollution from salt marshes, salt mines, and oil production.

Five of the 65 mil gal of oil field brine produced daily are going into the fresh waters. In addition, facilities for the secondary recovery of oil are injecting large quantities of salt water into the ground daily. When the brine distribution facilities and the repressuring wells are not carefully constructed and maintained, gross contamination of fresh water occurs quickly. This is a particular problem in southeastern Kansas.

Wastes from the salt mines at Lyons and Hutchinson add 190 tons of chloride to the Arkansas River each day. Our studies show that a third of this chloride seeps into the underflow of the river before it reaches Wichita, thus damaging not only the river flow but the underground waters. In November 1955 the Kansas State Board of Health adopted a policy for eliminating this waste from the river.

In addition to the industrial pollution, many tons of salt from natural sources enter the streams of the state. These require fresh water for dilution, and may therefore be considered an additional and partly unnecessary demand upon the available water supply.

Places in Kansas where municipal pollution makes water unfit for downstream use are becoming fewer and fewer, but several important ones remain.

Lack of foresight and inadequate planning were the causes of shortages in nearly two-thirds of the 175 Kansas cities which experienced difficulty. In most cities the warnings of shortages, had been occurring for several years, but these warnings had gone unheeded. In eight other cities, however, water works officials had anticipated shortages, but their advice was not accepted. In Kansas, it appears that citizens need 1–5 years to overcome natural inertia and make up their minds to build a major project; sometimes they take this much time on projects which are not major.

Increased Competition

During the drought of the 1930's, competition between farmers, industries, and cities caused problems; they were minor, however, compared with those which arose after 1951. For example, Russell, a city of 8,000, provided emergency facilities and pumped water into Big Creek, where it would flow to the city water works. Farmers, seeing water in the normally dry creek, pumped it onto nearby land for irrigation.

Beloit, a city of 4,000, was faced with a crisis in 1955 when upstream farmers started pumping water from the Solomon River for irrigation. Even though Kansas water law specifically dedicates all water to the state for appropriation, and provides that municipal water supply is one of the highest uses, the city was forced into a program of ground water exploration and the possible future development of low-yield wells.

A 12-month intensive study of the Republican River in 1948, as a part of the Kansas River basin pollution investigation, revealed the need for a minimum flow through Kansas of 50 cfs to provide dilution for treated municipal wastes. Through informal cooperation with the US Army Corps of Engineers, adequate releases have been made from the Harlan County Reservoir to maintain this flow. Diversions for irrigation at Guide Rock during the summer of 1955, however, reduced the stream flow to 20 cfs at Concordia. Not only do these diversions affect municipal sewage disposal, they reduce the amount of water of low mineral solids content available to dilute the more highly mineralized water from the Smoky Hill River. As a result, water in the Kaw River, formed by these two rivers at Junction City, exceeded the maximum limits for chlorides in drinking water.

The most widely publicized conflict over water rights in Kansas has occurred because of an anticipated shortage. It involves the use by Wichita and local farmers of a large ground water reservoir, the Equus beds, in Harvey and McPherson counties. These beds consist of extremely permeable sand and gravel deposits having a maximum depth of 280 ft. They contain 5½ times as much water as is found in all of the surface streams and impoundments in the state. In normal years this reservoir has remained full, with water constantly overflowing into the Little Arkansas river which bounds the reservoir on the east. The natural decline in water table during periods of drought, without pumping of any kind, has been as much as 10 ft. This decline over the entire Equus bed area, coupled with additional declines in the vicinity of the Wichita wells, has convinced many landowners that their water supply is endangered. As the city attempted to develop additional wells and lay collecting lines, suits were filed against it in both state and federal courts. These actions have hindered the city in its water development program and have forced severe rationing during summer months, even though water has been pumped from such emergency sources as sand pits, emergency wells, and ditches.

A study by the USGS and cooperating agencies shows that pumping by Wichita has caused a maximum water level decline of 30 ft and that the maximum area affected by pumping is 100 sq miles. The report shows that large supplies of water remain unused in the reservoir.

The increased use of water has caused problems of water quality aside from those of decreased rainfall. The use and reuse of water by twelve cities along the Neosho River accumulated enough detergent to form a suds on tap water. Several times during 1953–54, the total flow at each city water works intake did not exceed the sewage flow from the upstream community. Heavy pumping at the El Dorado–Augusta well field south of Wichita pulled Wichita sewage into the ground water aquifer, and the detergents reached a peak of 13 ppm. Failure of surface water supplies from a combination of drought and upstream irrigation forced the temporary use of water with as high as 1,600 ppm of chlorides and 1,038 ppm of sulfates.

Future Measures

One corrective measure is to make more water available. A sound water

resources program must be based upon the collection of essential data, the scientific analysis of these data and research for determining the fundamental principles of hydrology and the best methods for development and use of water. These basic data are necessary before answers can be made to questions such as the following: How will the available fresh water supply be divided between individual, municipal, industrial, and agricultural users? How will the costs of water developments be shared between users and the government? What are the responsibilities for all users to conserve water?

In addition to the collection of basic data, more water can be made available through a concurrent program of pollution abatement. Pollution from oil field brine in Kansas is still sufficient to render annually 1,000,000 acre-ft of water undesirable for human consumption. The pollution from natural sources is additive and is at least as great in magnitude. The construction of 165 new municipal sewage treatment plants in recent years has greatly reduced municipal sewage pollution, but the load from oil refineries and other industries is steadily growing. In addition, at least fourteen new municipal treatment plants will be needed each year to keep pace with normal community growth and plant obsolescence.

The available water supply to Kansas can be increased through a higher degree of development. That the average annual outflow from Kansas exceeds 10,000,000 acre-ft does not indicate that some of this water has not been used, but it does show the potential for more intensive or added use. By far the largest potential for the storage of water is in the ground. Improved farming practice to hold the water where it falls, and projects for recharging permeable ground formations in some areas, will increase the available water supply.

In addition, much water can be made available through the planned and intelligent use of existing ground water reservoirs with their 200,000,000 acre-ft of water in storage. This amount of stored water is equal to that which flows out of the state in a 20-year period. The potential of these reservoirs to supply large quantities of water during dry periods, with replenishment during wet periods, must not be overlooked.

The storage of excess surface water constitutes an important third element in meeting the demands for more water. Planning for reservoirs needs to be coordinated with other water resource projects.

The reduction of water wastage is important for all water users, particularly for those consumptive users such as irrigators. Industry, when faced by necessity, has found it possible to reduce its unit consumption by 50 per cent or more without affecting its output, and Kansas cities have reduced consumption by as much as 30 per cent without serious inconvenience to their customers.

In order to avoid municipal water shortages caused by inadequate planning and too little construction, cities should make an annual review of their water demands and the facilities which are needed to meet demands for at least 5 years into the future. Occasional reviews, brought about every 10–20 years by some crisis, are not enough.

The Kansas State Board of Health has assisted cities which were faced with emergencies caused by water

shortages. It has obtained mobile water purification plants, helped work out the procedures for the safe hauling of purified water, counseled on special treatment problems, made occasional laboratory investigations, maintained unusually close laboratory control in cities with deficient water supply, worked for the abatement of pollution, and has tried to direct attention in advance to factors which might contribute to a water shortage. If these efforts have been successful, much of the credit belongs to the conscientious and able water works officials in Kansas communities. The author has personally seen many of them working long hours, often with little public understanding of the importance of the job they were doing, to assure that their city has an adequate and safe water supply.

Correction

In the paper, "Recording Instrumentation in Water Treatment Plants," by Oscar Gullans (May 1956 JOURNAL), the recorder charts shown in Fig. 3 (p. 529) are incorrectly placed, through an editorial error. The charts, now labeled (*a*), (*b*), (*c*), and (*d*), should be, respectively, (*d*), (*a*), (*c*), and (*b*) in order to relate correctly to the text and caption.

Effects of pH and Velocity on Corrosion of Steel Water Pipes

Rolf Eliassen, Clemente Pereda, Amilcar J. Romeo, and Rolf T. Skrinde

A paper presented on Apr. 23, 1956, at the Canadian Section Meeting, London, Ont., by Rolf Eliassen, Prof. of San. Eng.; and Clemente Pereda, Amilcar J. Romeo, and Rolf T. Skrinde, Research Assts.; all of Sedgwick Labs. of San. Science, Dept. of Civ. and San. Eng., Massachusetts Inst. of Technology, Cambridge, Mass.

LOSSES from corrosion continue to be of major importance in municipal and industrial water supplies. The addition of various chemical inhibitors to water for the purpose of reducing corrosion has been practiced for a good number of years. Currently many different types of chemicals are being used or have been proposed for this purpose.

Although much is known about the effects of chemical corrosion inhibitors, there is considerable disagreement concerning the manner in which they limit the amount of corrosion. There is even some question whether chemicals commonly used as inhibitors actually inhibit corrosion or whether, in fact, they accelerate it. Extensive laboratory studies on the corrosion inhibition of sodium hexametaphosphate (*1–3*) have shown that differences in test results are frequently caused by differences in the methods of investigation employed.

Past Investigations

During early studies of the mechanism of corrosion inhibition by sodium hexametaphosphate, it was observed that, under certain conditions, pH and velocity could have an interrelated effect upon corrosion. Past investigators have published results which are at variance with the generally accepted theories of pH and velocity effects. The following presentation is based upon a study of these two basic factors as they affect corrosion in an actual pipeline network in the absence of chemical corrosion inhibitors.

Whitman and associates (*4*) classified corrosion of iron by water into three categories: alkaline corrosion, natural-water corrosion, and acid corrosion. In the natural-water range of pH 4.5–9.5, they stated that the corrosion products maintain a pH of 9.5 next to the metal regardless of the pH of the solution. In this range, therefore, they declared there would be no difference in corrosion rate.

Baylis (*5*) did not agree with the Whitman theory explaining the constant rate of corrosion in the pH range of natural waters. He believed instead that consideration of the solubility of iron at the different hydrogen ion concentrations might provide an explanation of the relationship of pH to corrosion of iron.

Upon investigation of the effect of oxygen concentration on the corrosiveness of distilled water at various hydrogen ion concentrations, Groesbeck and Waldron (*6*) presented data in sharp contradiction with the Whitman theory. In the Groesbeck and Waldron studies, the corrosion rate was higher at pH 7.0 than at pH 5.5. Fontana and Luce (*7*) reported similar results, in which low corrosion rates occurred at a pH of 6.0 and increased corrosion in the pH range of 6.0–8.0.

The effects of velocity on the corrosion of rotating discs and other simulating media have been quite consistent in reported studies, but these data are difficult to apply to pipeline flow. This is particularly true when analyzed from the point of view of fluid mechanics. Whitman (*8*) wrote in 1926 that the effect of velocity should be to increase corrosion due to increasing diffusion of oxygen and the breaking down of protective films on the metal surfaces. Friend (*9*) found that in certain cases increases in velocity might result in reduced corrosion.

Roetheli and Brown (*10*) rotated steel specimens in oxygenated Cambridge, Mass., tap water. As the rotational velocities increased, the corrosion increased to a maximum value, decreased to a low value, and increased again to a somewhat higher value at very high velocities. These variations in the corrosion rate were attributed to three factors: [1] differences in the type and uniformity of the corrosion film formed; [2] changes in film thickness; and [3] erosion. A maximum corrosion rate is reached at some veloc-

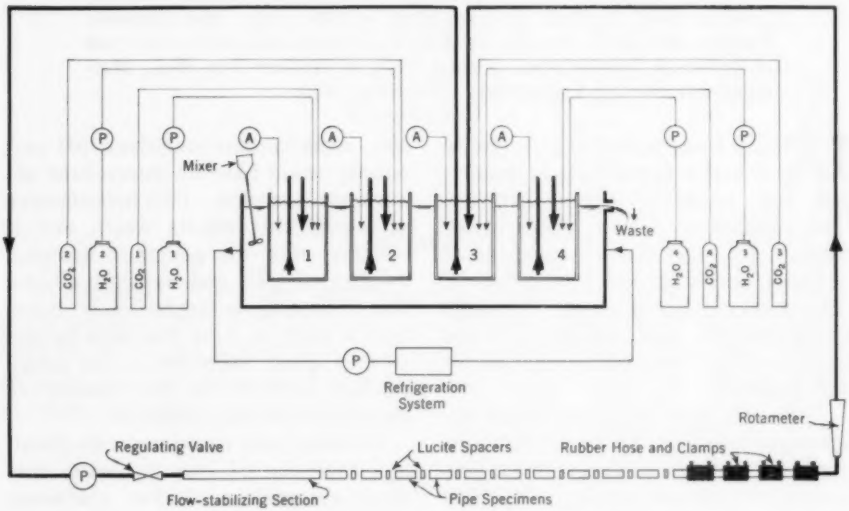

Fig. 1. Flow Diagram of Experimental Apparatus

Four identical simulated pipeline systems were maintained at constant temperature by temperature-bath control of four covered glass reservoirs, as shown in center. Circles marked A represent air supply, those marked P, pumps. Pump at lower left is stainless-steel centrifugal recirculator.

ity because of the presence of two opposing tendencies—the accelerated transfer of oxygen caused by a reduction in film thickness, and the increased rate of formation of a more protective film of corrosion products.

Evidence of a decrease in the long-term corrosion rates of steel pipes was shown by Passano and Nagely (*11*), who obtained weight loss curves with an initial phase in which corrosion seems to be proportional to time, giving a straight-line plot. This initial phase was followed by a progressive decrease in the rate of corrosion. The duration of the initial phase was shorter for the experiments conducted at higher velocities.

Speller and Kendall (*12*) found that corrosion of steel at higher temperatures increased with increasing velocity. At lower temperatures, the corrosion increased up to a maximum value, but there was no decrease in the corrosion rate. The effects of velocity and oxygen appear to be interrelated. High velocity may bring sufficient oxygen to the iron surface to cause passivity of the iron. This passivity may be caused by adsorption of oxygen at the iron surface, or by the formation of an oxide layer, as suggested by Uhlig (*13*) and Evans (*14*) respectively.

Objectives of Study

Many of the variations in test results have been caused by differences in the methods of investigation employed. Beaker tests often give results at variance with continuous-flow experiments, and duration of tests is an important factor. In order to provide a more realistic approach to the problem and to obtain test results most applicable to the water works industry, a pipeline network was built to simulate part of a water distribution system. These pipelines are operated under controlled conditions in the laboratory and afford the opportunity of observing any desired factor to predict what might happen under similar conditions of flow in an actual water distribution system.

The effectiveness of a corrosion inhibitor must of necessity be evaluated by comparing the measurements of corrosion in the presence of treated water with those in untreated water. As the effects of pH and velocity on pipeline corrosion seem, on the basis of work by past investigators, unpredictable, it has been necessary for the authors to study their effects in this particular pipeline network using water without inhibitors. This has established a corrosion datum plane upon which to base the fundamental studies on the effect of inhibitors.

This article presents the results of the initial phase of the investigations of the effects of pH and velocity on corrosion in the absence of inhibitors.

Experimental Apparatus

A flow diagram of the pipeline network is shown in Fig. 1, and a photograph of the actual equipment in Fig. 2. Each of the four identical pipeline systems was maintained at constant temperature by control of the temperature in the glass reservoir. Stainless-steel centrifugal pumps were employed for recirculation. The discharge from the pumps first passed through a section of pyrex tubing to straighten the flow before it came into contact with the test specimens.

The rate of flow through the system was measured continuously by means of a pyrex and stainless-steel rotameter before the water returned to the reservoir. A low-capacity pump was used

to feed fresh water into the reservoir continuously in order to replenish the corrosive medium and prevent excessive buildup of corrosion products in solution. Excess water was allowed to overflow from the reservoir to waste.

Procedure

Synthetic tap water was prepared by adding chemicals to demineralized water to form an "average" water—that is, a water of a chemical analysis comparable to that of many supplies in the eastern part of the United States. This water had a hardness of 84 ppm, a total alkalinity, by the methyl orange indicator method, of 57 ppm, and a pH after aeration of 8.05. Its pH_s was 8.28. The water was chlorinated daily. During the course of the experiments, the pH value of the water was adjusted to the desired value daily by addition of dilute hydrochloric acid or sodium hydroxide.

The pipe specimens were sections of steel pipe approximately 5 in. long. They were subjected to the standard cleaning procedures employed in the Corrosion Laboratory of the Massachusetts Institute of Technology. After weighing, they were assembled into systems by means of rubber hoses and hose clamps. Lucite washers between the specimens prevented galvanic or stray current effects. After removal from the system, visual observations were made of the corrosion products, and the specimens were again cleaned and weighed.

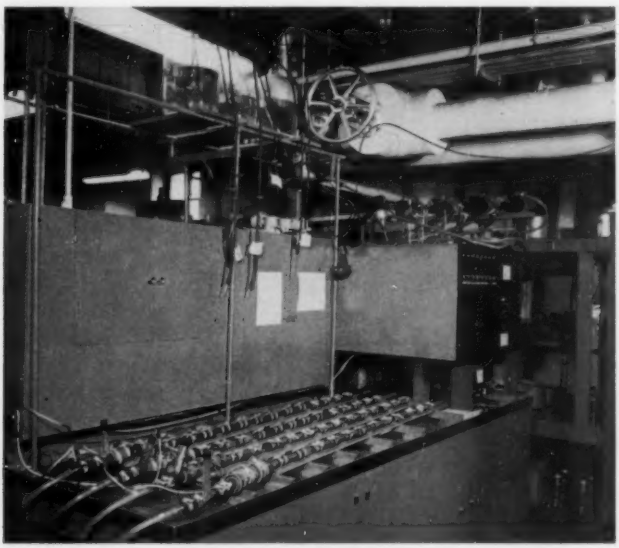

Fig. 2. Laboratory Equipment for Corrosion Studies

Water at controlled pH values and velocities was circulated through pipe specimens, connected by sections of rubber hose and clamps, visible in center foreground.

The temperature of the water was maintained at 20°C, and it was constantly aerated. Dissolved oxygen determinations were made daily, and hardness, alkalinity, and iron were determined weekly.

Observed Effect of pH

Preliminary short-term studies of the effect of pH on corrosion in untreated waters showed a slightly lesser degree of corrosion at pH 5.0 than at pH 7.0, decreasing again at higher pH values. Figure 3 shows this phenomenon for velocities of 0.33 and 1.0 fps and testing periods of 10 days.

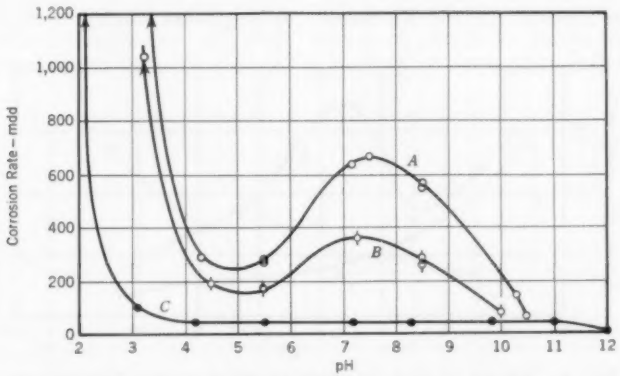

Fig. 3. Effects of pH and Velocity on Corrosion Rate of Steel

Curves A *and* B, *representing controlled velocities of 1.0 and 0.33 fps, respectively, indicate higher corrosion rates at pH 7.0 than at pH 5.0 for short-term tests of 10 days duration. At zero velocity, Curve* C, *the corrosion rate did not change over this pH range in short-term studies*

Further studies on untreated water showed quite clearly that duration of test runs has a pronounced effect upon the corrosion rate. It was found that in some cases the short-term test results were completely different from long-term effects. Figure 4 shows the effects of pH on the corrosion rate, as would be determined under tests of two different durations. The upper curve in this figure shows the 7–14-day corrosion rates and the lower curve indicates the 30–40-day corrosion rates. It is interesting to compare the curves thus obtained with the results presented by other investigators. The shapes of the curves obtained on the basis of short tests are remarkably similar to those obtained by Fontana and Luce (*7*) and Groesbeck and Waldron (*6*), and to the authors' own preliminary short-term tests. On the other hand, the curves obtained by plotting the 30–40-day corrosion rates are in good agreement with the generally accepted theories of Whitman and associates (*4*).

It appears quite reasonable to conclude that the differences in the results obtained by these investigators can be

attributed to differences in the duration of their experiments. Furthermore, if these results are applied to the overall corrosion phenomena, it would indicate that corrosion rates as determined by short-term tests are of less value than those determined by long-term tests.

The effects of pH on corrosion rates in the test interval of 30–40 days are shown in Fig. 5 for two different velocities. There was little change in the corrosion rates as the pH varied in the range of 6.0–9.0. At pH 5.6 there

There is good reason to believe, from the authors' studies of the effects of pH on corrosion, that some of the conflicting data reported in the literature may be explained if the length of test periods is taken into consideration. Short-term studies to determine the effects of pH, or the evaluation of other factors affecting the corrosion rate of steel, may be dangerous and should be interpreted with caution in relating the results to the long-range overall effects, since they may have little relationship to long-term studies.

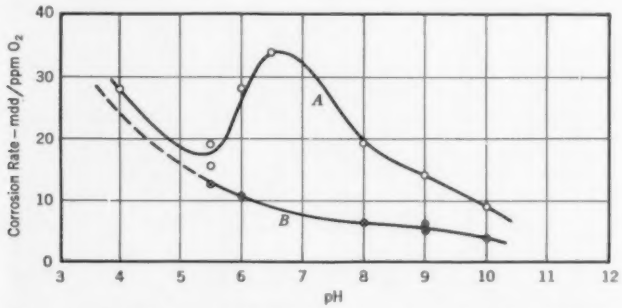

Fig. 4. Effects of Test Duration on pH-Corrosion Relationship

Points of Curve A *indicate corrosion rates established by 7–14-day tests, those of Curve* B *rates determined over a 30–40-day period. For both curves, velocity was maintained at 1.0 fps and pH controlled by the application of HCl and NaOH.*

was a slight increase in corrosion rate, which became more pronounced as the pH approached 4.0. The sharp decrease in the corrosion rate as the pH was raised to 10.0 was due to the deposition of calcium carbonate scale.

Very serious pitting was observed at pH 6.5. The pitting took the form of pinholes in large numbers and distributed longitudinally in straight lines. There was slight pitting at pH 8.0–10.0, but the pits were very few and shallow. No pitting was observed at pH 4.0 and 5.5.

The results of longer-term corrosion studies are apparently in agreement with the presently accepted theory of the effect of pH on the corrosion rates of iron as proposed by Whitman and associates (*4*). They attributed the constant corrosion rate in the pH range of 4.0–9.0 to a coating of ferrous hydroxide, which keeps the pH next to the metal at a constant value of 9.5. However, the results of these experiments indicate that the explanation of the effects of pH may be considerably more involved. Although it is true

that pH has little effect on the rates of corrosion, the type of corrosion may be affected considerably by variations in pH. This is substantiated by observations of the nature of the corrosion products, which are gelatinous and loosely attached to the metal in acid waters, and hard, raised, and well attached at pH values of 8.0 and higher. In addition, the serious pitting at pH 6.5 suggests that the mechanism of corrosion may possibly vary in the pH range of 4.0–9.0, even though the rates of corrosion remain practically constant.

The pitting obtained at pH 6.5 would considerably reduce the life of anodic control, signifying that the rate of corrosion is controlled by the rate of anodic reactions. The highly alkaline conditions throughout the liquid would result in almost immediate precipitation of the corrosion products as they pass into solution at the anodes. A tightly adherent anodic protective film would be formed, and this film would stifle the corrosion reaction by impeding the transfer of metal ions into solution.

In Zone 2, the corrosion would probably be under mixed control. The decrease in alkalinity causes rapid precipitation of corrosion products at the

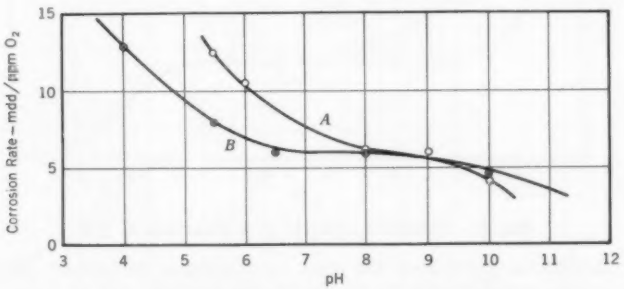

Fig. 5. Combined Effect of pH and Velocity

Curve A *represents a velocity of 1.0 fps; Curve* B, *a velocity of 2.0 fps. Tests were conducted over a 30–40-day period.*

the pipe. It would be of distinct advantage to avoid this pH whenever possible in water works practice, unless an inhibitor which operates effectively at this pH is added.

Mechanism of pH Effects

Based upon the studies of the effect of pH on the corrosion of synthetic tap water without inhibitor, using both weight loss and polarization tests, a tentative mechanism for the type of control has been determined, as shown in Fig. 6. At the high pH values of Zone 1, the corrosion would be under anodes, and there is increased tendency for the iron to go into solution. The cathodic reactions are controlled by deposition of calcium carbonate, because in this pH range the water would be supersaturated with respect to calcium carbonate. The cathode of the corrosion cell used in the polarization studies at pH 10.0 was completely covered with calcium carbonate, and there was a mixture of corrosion products and calcium carbonate on the anode.

In the pH range of 7.0–9.0, Zone 3, the corrosion would be primarily under cathodic control. A cathodic film

would be formed by precipitation of calcium carbonate. As the pH_s of this synthetic tap water was 8.28, it is likely that this value could be exceeded in the vicinity of the cathodic areas, as suggested by Raistrick (*15*).

In Zone 4, at pH 6.5, serious pitting was observed. This suggests partial anodic control. Polarization data at this pH also indicate that the corrosion is under anodic control. The initial rates of corrosion were higher than those obtained at a pH of 4.0, and the final rates did not differ greatly from those at pH 5.5 and 8.0.

The corrosion rate at Zone 5, pH 5.0–6.0, appears to be under cathodic control. The cathode of the polarization cell electrode was heavily coated with corrosion products, which were loosely attached and gelatinous in nature. The corrosion at pH 5.5 was very uniform, with little or no pitting. This would seem reasonable on the basis that as the pH decreases, the solubility of the iron salts increases, and the rate of corrosion product formation is delayed. The degree of anodic shielding, therefore, would decrease, and less pitting would occur. The decreasing pH favored more particles and more highly charged positive colloidal particles. Thus the protective cathode film, although somewhat eroded, would be replaced with increasing rapidity, and therefore would offer a more effective barrier against diffusion of oxygen from the solution to the metal surface. The corrosion

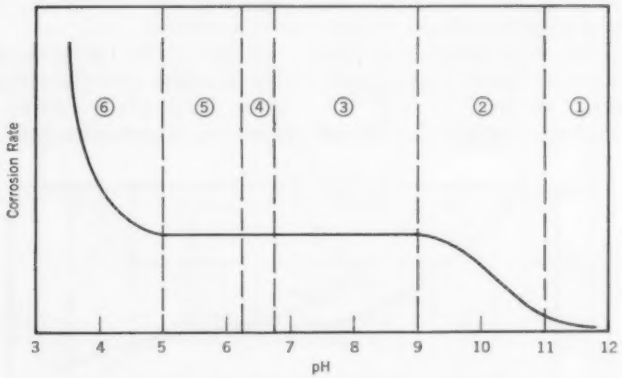

Fig. 6. Corrosion Control as a Function of pH

Conditions governing the rate of corrosion at various pH ranges are indicated by numbered hypothetical zones. Thus, in Zone 1, the rate of corrosion would be controlled by anodic reactions; in Zone 2, by mixed anodic and cathodic reactions; in Zone 3, primarily by cathodic reactions; in Zone 4, partially by anodic reactions (as indicated by serious pitting); in Zone 5, by cathodic reactions (as indicated by oxygen depolarization); and in Zone 6, by cathodic reactions (as indicated by oxygen depolarization and hydrogen evolution).

rate control would thus become more cathodic.

The increased rate of corrosion in Zone 6 could be attributed to one or more of several factors, the most obvious of which is hydrogen evolution. The increasing solubility of iron with decreasing pH in this range would result in the formation of fewer colloidal particles which might be deposited on the cathode. In addition, disruption of the cathode film by hydrogen evolution would tend to expose the metal to the water, resulting in increased ease of oxygen depolarization and hydrogen evolution. Thus it is indicated that Zone 6 is under cathodic control.

The foregoing hypotheses are stated here as proposed summations of the complex chemical, electrochemical, and physicochemical phenomena associated with corrosion in natural waters under variable pH conditions, as indicated by the results of laboratory studies to date. Further studies are being made to substantiate certain aspects of these hypotheses.

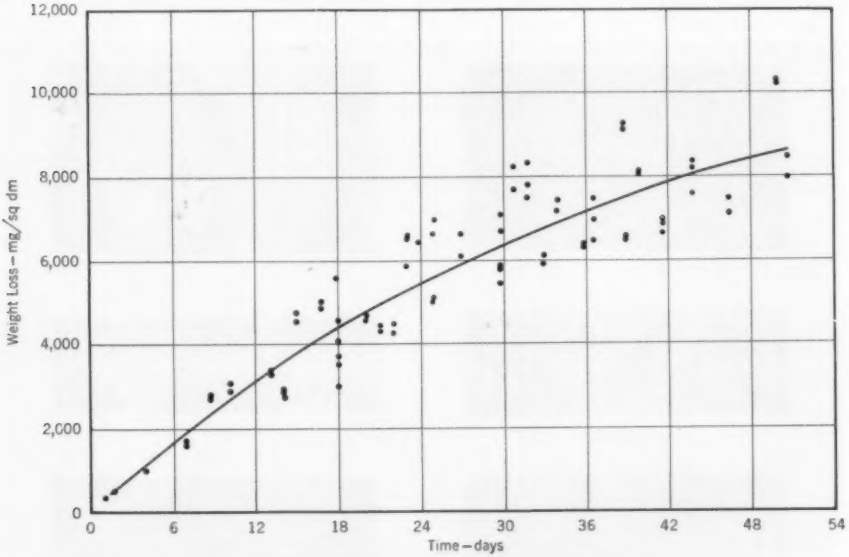

Fig. 7. Effect of Velocity on Corrosion of Iron

Points shown are from seven experiments run under identical conditions for 30–50 days on ¾-in. black-iron pipes, smooth and free of oxides. The velocity was maintained constant at 2.0 fps, the pH value at 6.5. The dispersion of points may be attributed to tolerances in machining and to pitting which occurred in some specimens.

Theoretical Velocity Effects

Present theories of fluid mechanics (*16, 17*) concerning boundary effects make it possible to deduce that the influence of velocity on corrosion will vary markedly with the type of surface and the characteristics of the flow. At low velocities (1–6 fps) in the range most often found in water pipes and mains, erosion and cavitation may

be disregarded. The later can be a very localized phenomenon in valves or other fittings. In general, pipe flow velocity will affect corrosion by the manner in which it supplies oxygen to the surface of the pipe and removes the corrosion products. This removal applies to metallic corrosion products such as iron hydroxides and oxides. Oxygen at the pipe surface may result in passivation or depolarization (*13*).

Most of the studies of the authors and others, as previously discussed—whether on rotating discs, stationary plates, or pipes—were made in the turbulent flow range. Turbulent flow destroys concentration and temperature gradients in the main body of the

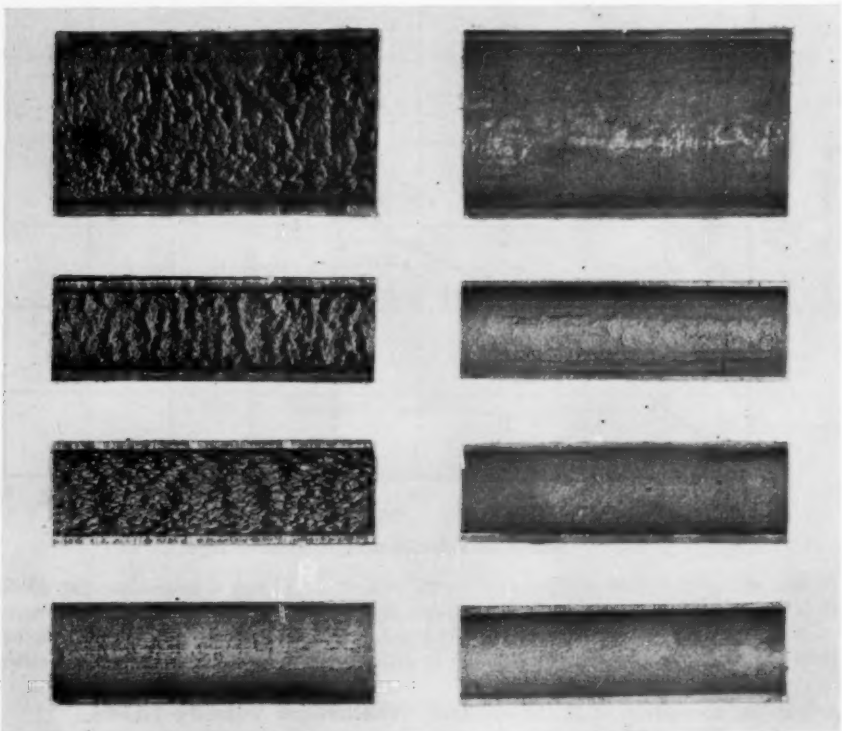

Fig. 8. Corrosion and Pitting of Iron Pipe Specimens

The upper three specimens show, at left, the conditions of the pipes before removal of corrosion products, and, at right, the pipes after cleaning. No pitting is observed. The sample at the top shows effects of corrosion on 1½-in. pipe at pH 6.5 and a velocity of 1.0 fps. The second sample shows corrosion of ¾-in. specimen at pH 6.5 and 2.0 fps. The third sample shows corrosion of ¾-in. pipe at pH 8.0 and 3.0 fps. The samples at the bottom are cleaned specimens of ¾-in. pipe tested under the same conditions as the second sample above. Some samples, such as that at left, showed pitting, while others, such as that at right, showed no pitting. All specimens were taken after 40 days of testing.

fluid. All of the actions affecting corrosion will take place in the boundary layer of fluid adjacent to the pipe wall. This layer follows different laws according to the way in which flow proceeds past the corroding specimen. Taking three of the most commonly employed techniques used in studying corrosion—rotating discs, flat plates, and pipes—flow characteristics can be deduced from a study of these laws.

In the case of a rotating disc, the tangential component of velocity at any point will depend on the angular velocity and the radius. A radial component of velocity will also exist, just as in a centrifugal pump (*17*). With a stationary flat plate in a moving body of liquid, as used by Streicher (*18*), a boundary layer, initially laminar, will form at the leading edge. This layer continues from the leading edge to a point downstream where the flow adjacent to the metal may become turbulent if the conditions are favorable. With turbulent flow in pipes such as those used in the experiments reported herein the laminar layer is a very thin sublayer, measured in thousandths of an inch. The remainder of the flow is turbulent. This laminar sublayer may exist only in smooth pipes, before corrosion proceeds very far. Because the corrosion products create roughness, they tend to destroy this boundary sublayer and cause turbulent flow to approach the pipe wall, or the outer surface of the corrosion products.

From the foregoing examples referring to different methods of testing it can be appreciated that the same velocity may lead to conditions of flow at the corroding surfaces which may be very different. It is not surprising that so many discordant opinions exist on the influence of velocity when different experimental approaches are employed. It is important, therefore, to simulate conditions found in water works practice.

Assuming that the laminar sublayer exists at the beginning of the tests on smooth pipes, oxygen will have to diffuse from the main body of turbulent water through this sublayer to the pipe surface. The corrosion products will have to diffuse in the reverse direction from pipe surface to the rapidly flowing water. It has been shown (*17*) that the thickness of the laminar sublayer is directly proportional to the kinematic viscosity of the water and inversely proportional to a fractional power of the Reynolds number.* The higher the velocity, the thinner the laminar sublayer. The foregoing has been developed more extensively in a thesis by Shifrin (*19*). Fick's law of diffusion states that for any given area the rate of diffusion is proportional to the gradient of concentration. This gradient will increase as the thickness of the laminar sublayer decreases. Thus the initial corrosion rate will be proportional to the velocity. From theoretical considerations it may be shown that the initial rate of corrosion is a function of velocity to a fractional power of about 0.8.

This is in good agreement with some authors such as Speller (*20*), whose results of initial corrosion rate plotted against time seem to follow a similar law, with a fractional power of about 0.5 in the velocity range of 0.5–2.0 fps. At velocities greater than 2.0 fps the plots virtually follow a straight

* A dimensionless number equal to $\frac{Du\rho}{\mu}$, where D = pipe diameter in feet; u = fluid velocity in feet per second; ρ = density in pounds per cubic foot; and μ = absolute viscosity.

line, which is probably due to the fact that at a higher Reynolds number the roughness of the pipe is of higher order than the thickness of the laminar sublayer that is destroyed.

Experimental Results

Using a ¾-in. pipe with a velocity of 2.0 fps, the authors found that the results presented in this paper followed the same trend, but with a lower power of velocity (0.4–0.5). Figure 7 shows a plot of total corrosion in milligrams per square decimeter against time (in days) for seven experiments. These were run under identical conditions for 30–50 days, and on ¾-in. black-iron pipes which were smooth and free from oxides at the start. The dispersion of the points may be attributed to tolerances in machining and to the pitting which occurred in some specimens. The photographs in Fig. 8 show the variations in pitting occurring in different samples under specified conditions of pH and velocity.

From statistical analyses, it has been found that the equation fitting the distribution of points is of the form:

$$C = K(1 - e^{-kt})$$

in which C is the total corrosion, K a constant of the same units as C, k a constant which is a reciprocal of time, and t the time after starting each run. This follows the logic that corrosion decreases with time due to the protective effect of the increasing layer of corrosion products. Using the same basic equation and changing the coefficients to observed results, other curves for 1, 3, and 4 fps have been plotted. In Fig. 9 it may be seen how well experimental results in the postulated curves for each of these velocities up to 50 days.

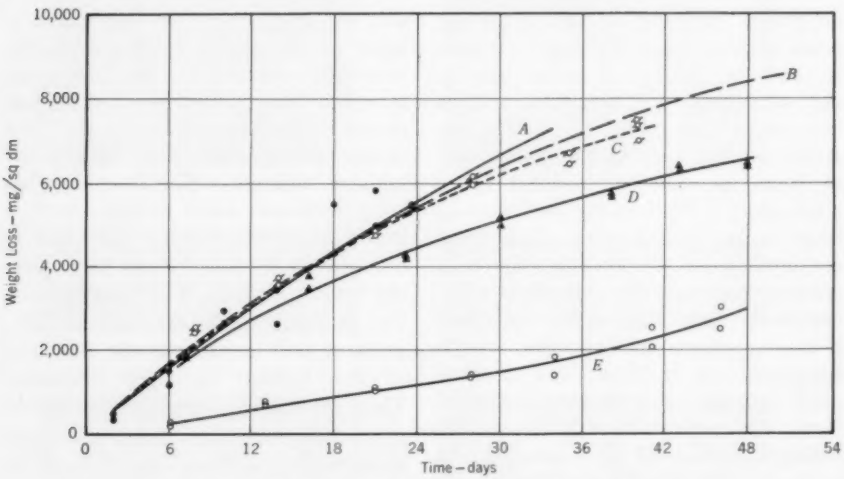

Fig. 9. Effects of Velocity on Corrosion of Iron

Curves show effects of various velocities on the corrosion of black-iron pipe, using synthetic tap water at 20°C at a controlled pH of 6.5. Velocities shown are: A—*1.0 fps;* B—*2.0 fps (curve plotted from Fig. 7);* C—*3.0 fps;* D—*4.0 fps;* E—*0.125 fps.*

The equation would indicate that corrosion tends to cease as it approaches a maximum value K. This is not generally true, because experience has shown that corrosion continues to proceed with time, although at a low rate. It can be deduced that in the period studied the corrosion tends toward a state of dynamic equilibrium. Once reached, corrosion occurs at a constant rate, the equation being transformed to a linear one of the form:

$$C = c + mt$$

in which C is the total corrosion, c the corrosion prior to the time at which this equation begins to apply, m the constant corrosion rate, and t the time. Only long-term runs will show if the ultimate rate will be a function of the velocity or of some other factor dependent on the other variables affecting the size, roughness, and composition of the corrosion product layer. In such event, velocity will affect only the time necessary to reach the equilibrium state.

Conclusions

On the basis of results obtained from this investigation, it may be concluded that:

1. Short-term tests in corrosion rate studies must be evaluated with caution, as the results from such tests may not conform with results from long-term studies.

2. Variations in pH in a range of 5.5–9.0 resulted in little change in the long-term corrosion rates of iron at a particular velocity. Increase in pH to a value of 10.0 resulted in an appreciable decrease in the corrosion rate, and a decrease in pH to 4.0 increased the corrosion rate markedly.

3. Very serious pitting occurred in many specimens at pH. 6.5. Little pitting was observed at other pH values investigated.

4. A tentative hypothesis, which covers corrosion phenomena over the pH range 4.0–10.0, is proposed.

5. As long as the laminar sublayer exists, the corrosion rate is a function of the velocity raised to a fractional power.

6. The corrosion rate decreases with time and follows an exponential law derived from the equation $C = K(1 - e^{-kt})$.

7. The corrosion rate finally reaches an almost constant low value and does not cease with time.

8. Studies of the effects of velocity on corrosion rates will have to be correlated with a study of the physical and chemical characteristics of the corrosion products layer under each condition of pH and velocity.

Acknowledgments

The authors are indebted to James C. Lamb III, Walter G. Shifrin, and Joseph Sideransky for their past work on this research project, and to Herbert H. Uhlig, Director of the Corrosion Laboratory of the Massachusetts Institute of Technology, for his counsel. This work has been supported financially by the Corrosion Research Council of the Engineering Foundation, by the National Science Foundation, and by the American Iron and Steel Institute.

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Effects of Plastic Pipe on Water Quality

Walter D. Tiedeman and Nicholas A. Milone

A summary of the research report, "A Study of Plastic Pipe for Potable Water Supplies," of the National Sanitation Foundation, by Walter D. Tiedeman, Exec. Director, and Nicholas A. Milone, Research Assoc., both of the National Sanitation Foundation Testing Lab., School of Public Health, Univ. of Michigan, Ann Arbor, Mich.

THE wide interest in the use of plastic pipe for conveying water and the native caution of health officials in permitting the use of new and untried substances in contact with the public's drinking water established the need for a study of the suitability of plastic pipe for potable water supplies.

The work was sponsored by the Society of the Plastics Industry for its Thermoplastic Pipe Division and for suppliers of plastic materials. The advisory committee composed of R. J. Faust, C. W. Klassen, O. J. Muegge, B. A. Poole, R. O. Saxvik, and J. H. Svore, representing public health, and E. M. Adams, P. S. Britton, W. E. Jacobson, W. E. McCormick, and J. S. Whitaker, representing industry, met often and took an active part in reviewing and discussing progress reports and in directing the study. These contributions as well as aid in editing this final report are hereby gratefully acknowledged.

Scope of Project

The studies, which extended over a period of 3 years, were made of 22 samples of four types of plastic pipe to determine their suitability for underground use in conducting cold potable water. The tests performed were designed to show whether any substances that might be deleterious to health would be extracted from the plastic by an aggressive potable water and whether the passage of water through plastic pipe might affect the appearance, odor, or taste of the water. The physical properties of plastic pipe were not tested as this is the subject of a separate study being conducted elsewhere.

It is recognized that the composition of plastics varies to such an extent that results obtained in testing one formulation are not necessarily applicable to all products known as plastic pipe. The 22 samples selected for study included the plastics most commonly in use for conducting cold water as well as some proposed new formulations and, for comparative purposes, a few plastics not recommended for use with potable water. These samples are classified broadly as polyethylene, polyvinyl chloride, rubber-modified polystyrene, and cellulose acetate butyrate.

Test Results

A number of reputedly aggressive natural waters were used in prolonged contact with segmented pipe in jars to determine which water was most likely to extract substances from the plastic.

It was found that the most aggressive water was a relatively soft water with the pH adjusted to about 5 by adding carbon dioxide. This water extracted lead compounds from specially prepared test plastics and also extracted color from a special test sample made of electrical-insulation grade of polyethylene. It was decided to use Ann Arbor water, which is chlorinated and fluoridated, with adjusted pH, throughout the tests.

Extraction

A procedure was developed for subjecting cut specimens of plastic pipe to extraction by aggressive water. The results of the extractions were negative for all specimens of plastic pipe recommended for use with potable water. Routine chemical examinations of the water used for these extractions, as compared with the water after exposure to the various plastics, showed no significant changes.

In order to demonstrate that the test water was aggressive enough to extract certain substances from plastic pipe, special specimens were introduced of formulations not recommended for water supply use. Color was extracted from a sample of polyethylene pipe made from electrical-insulation material and 0.34 ppm of lead was extracted from a sample of polyvinyl chloride pipe containing a lead compound. Both extractions were with Ann Arbor water at pH 9.6.

To test the effect of pH, samples of plastic formulations were produced experimentally, in sheet rather than pipe form, containing considerable quantities of lead, cadmium, and barium. The amount of lead extracted was greater for the sample containing larger amounts of lead and increased with the acidity of the test water.

Very small quantities of cadmium were extracted from samples containing considerable cadmium, but no barium was extracted from any of the samples, even with the pH of the water lowered to 1.1.

Weathering

To determine the effect of natural weathering, samples of plastic pipe were exposed outdoors under standardized conditions for a period of 1 year. There were slight changes in color in a number of instances and a fine surface film formed on the sample of rubber-modified polystyrene.

Exposure to Soil

Very little effect on any of the test plastics resulted from burial in an acid soil of pH 2.0 in open glass jars held at 35°C for 1 year with intermittent wetting and drying using distilled water to simulate rainfall. Some discoloration of the plastic resulted and a tendency was noted for formation of a film at the soil-plastic interface. A copper pipe similarly tested showed considerable oxidation and deposition of film, while a galvanized-steel pipe control showed pronounced deposits at the soil-metal interface.

Exposure to Water and Air

Pieces of the test plastic pipes cut in half lengthwise were held partially immersed in the test water in sealed large-capacity glass-stoppered bottles at 35°C. Upon examination these test pieces showed slight color changes, slight film formations, and, in some instances, a slight fungus growth. The control, consisting of copper tubing held under identical conditions, showed a fine black sediment and the galvanized-steel pipe control was covered with a heavy white deposit.

Taste and Odor

Taste and odor studies were made by a panel of five selected members. Tests were made on warmed water by the standardized procedure, the samples being identified simply by number. Controls of test water that had not been exposed to plastic and of odor-free water were included. As an additional control, water exposed to segmented copper pipe was used.

The waters exposed to plastic pipes were found not to have any greater intensity of odor (as indicated by threshold number) than did the controls. An attempt was also made to describe tastes, although it is recognized that taste is largely influenced by odor. There was a tendency to describe the tastes and odors observed as chemical or medicinal. This included the controls and may be, to some extent, a result of the test water's being chlorinated. This procedure did not take into account the possible effect of fittings and jointing compounds. It should be remembered that exposure conditions were purposely severe in these tests and will probably not be duplicated in severity under any normal conditions.

In order to include the effect of fittings and jointing compounds, additional tests were made using water alternately recirculated for 30 min, then held quiescent for 30 min, for extended periods through systems of plastic pipe to simulate conditions in a water supply system. Differences tending to make this test more severe were that the water was at room temperature and was recirculated, whereas in a water supply system the water probably would be cooler and the contact period shorter.

The results showed no intensity of odor greater than that of the galvanized-steel pipe control similarly operated. There was one exception and this was overcome after the system was properly conditioned before the water was circulated. In that instance, a threshold odor of 150 was obtained on water recirculated through cellulose acetate butyrate pipe assembled by the use of a highly volatile solvent and cement furnished by the manufacturer. After this system was emptied and air circulated through it for several hours followed by flushing with water, the odor was reduced in intensity until it was no greater than that of the controls. After standing empty and closed for several days, however, this system still gave off the characteristic odor of the solvent. It is understood that the manufacturer is changing this solvent.

The results of testing this recirculated water for taste were similar to those reported above on water in contact with segmented plastic pipe.

Effect on Chlorine Residuals

Tests were performed to determine the effect, if any, of plastic pipe on chlorine residuals in water. It was found that water containing 0.8 ppm chlorine by orthotolidine-arsenite test (of which 0.1 ppm was free chlorine) placed in contact with segmented plastic pipe maintained a residual of at least 0.1 ppm of free chlorine for 5 hr or more. In no instance was the reduction of the residual of free chlorine great enough to change materially the effectiveness of chlorination of potable water delivered through plastic pipe.

Disinfection

Tests were performed to determine whether systems of plastic pipe could be satisfactorily disinfected by the standardized procedure. Recirculating systems of each of the four types of

plastic pipe under study were heavily seeded with cultures of *Esch. coli*. After draining, the solution of chlorine was recirculated to disinfect the system. The results showed satisfactory disinfection. Either *Esch. coli* were not recovered after disinfection or the number recovered was insignificant.

In experiments using high concentrations of chlorine, excellent results were obtained in disinfecting systems with no adverse effects on the plastics after 20 hr of exposure at 10°C. Adverse effects on copper and galvanized-steel specimens were noted, however, when such pipes were held under similar conditions. This indicates that higher concentrations of chlorine may be used if desired without damage in the disinfection of plastic pipe.

Animal Feeding

As a final test of possible deleterious effects of plastic pipe on potable water, colonies of Wistar-strain white rats exclusively for 18 months drank water that had been in prolonged contact with various plastics. The rats were divided into seven groups, each composed of five males and five females. They were housed in individual cages. Normal laboratory practice was followed in the observation, feeding, and care of these rats.

Observations and tests of rats dying or sacrificed before the expiration of the 18-month period as well as of the 36 sacrificed at the end of that period showed no appreciably abnormal effects as compared to the control group. Growth, food consumption, and water consumption were similar in all groups. The blood showed no significant changes. None of the groups showed significant variations in weight as compared with the controls. Two groups showed decreases in weight during the last 10 weeks as a result of the chance death or sacrifice of the heavier rats in such groups. The results of autopsies showed no evidence of any damaging actions finally attributable to the test chemicals.

The group of rats fed on water in contact with special specimens of plastic pipe containing lead, cadmium, and barium did not show any deleterious effects of possible extracted chemicals. The quantities of lead in the blood at the end of the feeding period were not excessive.

Susceptibility to Rodent Attack

All classifications of pipe tested were shown to be susceptible to rodent attack when the pipe was used in controlled experiments designed to obstruct access to food. Possibly because of the softer texture of polyethylene it was particularly susceptible to attack. In these experiments, both the Norway or so-called brown or sewer rats, *Rattus norvigicus*, and the rat commonly called the roof, gray, black, or climbing rat, *Rattus rattus*, were used. Under the test conditions it was evident that plastic pipe may be attacked by either of these types of rat. There was no evidence that the rats ate the plastic nor that they gnawed it in preference to other substances.

Addenda

Differentiation of plastics. Two methods of determining the general types of plastic in the pipe formulations tested, one by specific gravity and the other by flame test, are described in Appendix B of Part II of the report.

Test procedure for other formulations. As previously stated, the results reported herein apply only to the particular samples tested. A rapid test

procedure which may be applied to other types of plastic was developed during the study and is described in Appendix C of the report. For samples containing substances of unknown toxicity, a lengthy procedure involving the feeding of test animals is recommended to determine possible toxic effects.

Identification of satisfactory plastic pipe. For the guidance of users of plastic pipe for conducting cold potable water, the National Sanitation Foundation Testing Laboratory is cooperating with extruders of plastic pipe and suppliers of materials in developing a plan for identifying satisfactory pipe. This is to be announced later.

Approval. The results of this study have been reviewed and approved by the public health members of the advisory committee.

EDITOR'S NOTE: With the basic acceptability of plastic pipe from a public health viewpoint established, the primary problem of standardization of dimensions and fittings still remains before the extensive application of plastic pipe in the water works field can be considered entirely practical. Working on that problem now is a subcommittee of ASA Committee B16, charged with developing specifications for plastic pipe fittings. AWWA is represented on the fittings subcommittee. There are other standards available and in preparation, including an ASTM standard on both materials and methods of testing, but the reduction of the present multitude of designs, dimensions, and materials into a standard range of sizes and types awaits the completion of the ASA project in, perhaps, 2 or 3 years. While plastic pipe is being used in several water systems on an experimental basis, the Water Works Practice Committee does not as yet have sufficient evidence of standardization in the production of plastic tubing and fittings to justify adding them to its list of acceptable service line materials.

Plankton Populations in Indiana's White River

James B. Lackey and Eugene R. Hupp

A contribution to the Journal by James B. Lackey, Prof. of San. Science, Univ. of Florida, Gainesville, Fla., and Eugene R. Hupp, formerly Chief Chemist, Indianapolis Water Co., Indianapolis, Ind.

IN recent years, people have become increasingly conscious of the existence of algae. Because algae are not always recognized as such, the terms green moss, green scum, or water moss are used in referring to growths in lakes, ponds, and streams. When a lake in which people swim or fish, or upon whose banks they have a summer cottage, begins to bloom with a thick suspension of algae, there is an immediate outcry to health or sanitary officials. When rivers turn green with their late summer crop of plankton organisms the reaction is about the same, but if the stream is used as a water supply, the difficulties may be complicated because of tastes and odors in the drinking water.

Most of the problems having to do with water quality in rivers are caused by plankton algae and protozoa. Plankton algae are the suspended free-floating or free-swimming microscopic plants containing chlorophyll, although, in addition to this green pigment, there may be other colors, and the organisms may vary from green through olive green, blue, brown, or red. Practically inseparable from the algae are the plankton protozoa, also microscopic in size, but which are animals, usually colorless. There are also other minute animals in the plankton, such as rotifers, worms, and the young of larger animals, but the protozoa are the most abundant.

Different streams vary greatly as to the quantity and quality of their plankton and the plankton content of a single stream will fluctuate widely from time to time. Some streams, whether creeks, small rivers, or large rivers, contain many plankton organisms (*1–5*). In others, the quantity is negligible. The factors determining the quality and quantity of stream plankton are presumably multiple and interrelated, and they are therefore difficult to evaluate. On rare occasions a single factor seems to be of sufficient importance to outweigh all others (*6, 7*), and such a factor is usually a restrictive one.

Domestic sewage has frequently been assumed to be the principal factor increasing plankton production in streams (*8–11*), but this has not been conclusively proved, and recent studies (*12, 13*) have shown that enormous quantities of plankton may be present in small streams and rivers which either receive no sewage or are far removed from sewage pollution. It is almost impossible to separate the effects of domestic sewage from those of trade wastes for the following reasons: [1] there are few communities capable of adding effective amounts of sewage which do not also contribute some industrial pollutants, and [2] the specific effects of most trade wastes upon plankton are still largely unknown. Increase of plankton downstream from

a community contributing sewage should be carefuly investigated before the increase is blamed wholly upon sewage.

Purification Problems

Plankton abundance in raw water is of considerable importance to water purification. It may add measurably to the expense of color, odor, and taste elimination, and it frequently shortens filter runs, leaving in the filter sand a gelatinous deposit which is difficult to break up. The accumulation of dead and dying plankton in the filter sand offers an excellent substrate for the growth of such bacteria as *Pseudomonas*, an organism which passes filters more readily than larger rod-shaped forms. Because members of this genus are possibly concerned with gastroenteric disturbances in man, a rich plankton may thus indirectly be connected with waterborne gastroenteritis. Such problems as these make the investigation of plankton relationships in streams a promising field for research.

White River Characteristics

The White River supplies water to several Indiana cities, including Indianapolis. This river has long been noted for its high plankton content (*14–16*), and data covering a period of several years are available. Chemical data from the records of the Indianapolis Water Company and the Ohio River Pollution Survey (*17*) are also available, and conditions below Indianapolis have been studied by Denham (*16*) and Calvert (*18*). These last two studies take into account the effects of the Indianapolis sewage treatment plant effluent. The composite picture of all these studies shows a stream with indexes of pollution which rise and fall repeatedly, both as to length of area covered and as to gage readings at a given point.

Table 1 gives some indication of this pollution, as measured by numbers of coliform bacteria and the 5-day BOD. According to this table, the various towns seriously pollute the river, but natural purification reduces the load before the next town is reached. Below Indianapolis the flow is sufficient to carry the pollution loads of other towns on the river. Upstream, the BOD loading of the river remains somewhat high for about 65 miles below Winchester, but despite this, DO frequently reaches a point of supersaturation.

Practically all the determinations in Table 1 were made in the late summer, a time of high temperatures, low flows, greatest stream clarity, and highest plankton production. It is also the time when the highest relative amounts of sewage and trade wastes might be expected. The BOD values of the section below Indianapolis, therefore, might be caused by plankton content of the water, rather than by sewage or industrial wastes. As to the plankton of the whole river, it is pertinent to compare its quality and quantity with plankton of other rivers and to evaluate the effects of watershed population, effects of towns (their domestic sewage and wastes), the age of the water, and other specific environmental factors. Finally, it might be useful to investigate the effects of plankton upon water treatment as shown by the Indianapolis water purification plant, which uses a large proportion of the stream flow at low-water periods.

Plankton Groups

As shown by Table 1, the river was somewhat arbitrarily divided into five

sampling zones. Zone *A*, from the headwaters to just above Muncie, might be regarded as a region of creeks. This headwater region is densely populated and agriculture is intensively practiced. Winchester, the largest town in this area, has a population of about 4,500 and is located on the stream. In effect, the river practically begins its existence as a fertilized stream.

Zone *B*, beginning just below Muncie, is one of heavy fertilization because of the size of the city (50,000 population) and the smallness of the stream. Because of the steep gradient, riffles, and dilution, there is a rapid recovery of the stream in the next 20 miles, and the region from Anderson to the canal headgates at Indianapolis—the 53 miles comprising Zone *C*—might be regarded as showing little evidence of serious pollution.* Zone *D*, beginning at Indianapolis, is again heavily polluted, and this pollution continues downstream for 25–35 miles to below Martinsville, although the DO shows an adequate recovery some distance above Martinsville. Zone *E*, from below Martinsville to the mouth of the river, is a region of no large cities. There is a large flow in the river, turbidity drops, and DO remains high.

TABLE 1

Characteristics of the White River

Station	Zone	Distance From River Mouth *miles*	Flow, Sep. 1, 1940 *cfs*	DO Content—*ppm*		5-Day BOD—*ppm*		Maximum Coliform Bacteria per 100 ml, Below Station	Maximum Turbidity *ppm*
				Above Station	Below Station	Above Station	Below Station		
Winchester*	*A*	438	1	4.0	1.9	5.1	6.8	24,800	83
Muncie	*B*	410	9	8.7	0.0	2.5	43.7	673,000	90
Anderson		390	61	7.5	4.0	4.4	5.4	2,460	40
Noblesville	*C*	361	55	11.6	7.6	6.5	7.6	264	25
Canal headgates at Indianapolis		337	69	5.7		2.5		15	17
3½ miles below Indianapolis	*D*	325	131		2.9		9.1	23,200	9
Martinsville		291	154	9.9	10.0	8.2	8.2	1,880	10
Spencer	*E*	261	181	10.4	12.8	6.4	6.7	261	13
Above Eel River		236	254	9.3		6.0		4	13
Below Eel River		232	286		8.3		3.8	41	29
Washington		161	323	9.4	9.4	3.3	6.4	22	22

* Winchester is between 5 and 10 miles from the origin of the river.

Table 2 shows the number of samples taken in these zones and the percentages for each zone. Most of the samples in Zone *A* were taken in No-

* The Indianapolis treatment plant does not take its supply directly from the White River, but from a canal which takes off the river upstream from the city, passing through Indianapolis, and then rejoins the river. The canal was originally built in 1837 as part of the inland waterways system.

vember 1945, but water temperatures were 10–11°C and the summer organisms were still present. Table 3 shows the groups of algae and protozoa found, the number of species in each, and their distribution by zones. Considering the relatively small number of samples (89 in only 4 months), the 305 species found is a large number. A review of available literature (*19*) has shown three other streams in which this number has been exceeded: the Scioto River of Ohio, the Ohio River, and Tanner's Creek of Southeastern Indiana. For these three streams, the numbers of samples were 1,327, 66, and 171, respectively, but all seasons of the year are represented in the studies. A longer study of the White River might have greatly increased the species list, and a more critical examination of certain genera, as in the diatoms, for example, might also have augmented the list. For the season considered, the list probably includes practically all the common species. In three or fewer samples, 104 species were found, and only 12 species occurred in 50 or more samples.

TABLE 2

Distribution of White River Samples

Zone		July	August	September	November	Total	Percentage of Total
A	Above Muncie to source		2	1	5	8	9
B	Above Anderson to Muncie	1	2	1	5	8	17
C	Above Indianapolis to Anderson	3	1	37	1	42	47
D	Above Martinsville to Indianapolis			7			8
E	Below Martinsville			16	1	17	19
	Totals	4	7	65	13	89	100

Plankton Occurrence

Table 3 presents the ratio of actual occurrence to potential occurrence for those organisms which were found present in the samples. This table is based on the assumption that if a sample is large enough and is completely examined, a species encountered at a sampling station should occur in all samples taken at that station. That this assumption does not hold is proved by the failure in finding a given species in all samples examined from the station. Nevertheless, that species has a potential 100 per cent occurrence. An increasing frequency of its occurrence, up to 100 per cent, and the appearance of large numbers of individuals, indicate the degree to which the environment is favorable for it. This, in turn, enables environments to be compared in the search for favorable and unfavorable factors. When this procedure of checking actual occurrence against potential occurrence is applied to all species, it effectively separates those which can tolerate a wide range of environment from those which have limited tolerance or which may find the favorable environmental factors at a low-concentration level rather than near optimum levels. Species not found at all are not considered; those whose percentage of possible occurrence is very low find the environment unfavorable and those whose percentage is high find the environment favorable. A high percentage of occurrence,

in combination with low numbers of individuals, indicates some environmental limitation such as a deficient food supply.

The percentage of species in each zone and the total occurrence of all species in each zone follow the percentage of samples in each zone remarkably well. There were 48 species which occurred in all five zones, and 101 species occurred in only some single zone. Those which occurred in all zones are organisms which are generally widespread, unless some single, highly restrictive factor is operative. As evidence of lack of such a factor, the species which occurred in only a single zone were species not abundant as a rule, although, in one case, there were many of them, indicating some special environmental factor in that particular river stretch.

As shown in Table 4, the average numbers per sample of any given species generally tend to rise to a maximum in Zone *C* and then decline. Although exceptions to this could be shown, the trend is there. The low numbers per milliliter near the headwaters may be caused by the lack of necessary fertilizing material, insufficient age of water, or both. The midsection is generally well enriched, has aged materially, and has had a great variety contributed by inflowing streams. In the lower reaches, nutrient material tends to disappear, which may be of critical importance for some of the scarce nutrients such as soluble phosphorus, which is removed by nonbiological action (tricalcium phosphate) as well as biological action. Sawyer and Lackey (*20*) have shown that less than 0.015 ppm of soluble phosphorus may be highly restrictive to plankton algae. Repeated analyses, such as those by Hupp (*15*), indicate

TABLE 3

Plankton Occurrences in Various Zones

Plankton	Number of Species Present	Theoretic Number of Occurrences	Actual Number of Occurrences	Percentage of Theoretic Occurrences
Zone *A*—8 samples				
Fungi	2	16	2	13
Myxophyceae	6	48	12	25
Bacillarieae	16	128	45	35
Dinophyceae	3	24	6	25
Cryptophyceae	6	48	21	44
Chrysophyceae	8	64	13	20
Heterokontae	1	8	1	13
Euglenophyceae	29	232	66	28
Volvocales	9	72	18	25
Chlorophyceae	32	256	53	21
Sarcodina	3	24	3	13
Mastigophora	7	56	9	16
Infusoria	12	96	19	20
Total	134		268	
Zone *B*—15 samples				
Fungi	2	30	4	13
Myxophyceae	5	75	12	16
Bacillarieae	18	270	85	31
Dinophyceae	2	30	7	23
Cryptophyceae	5	75	34	45
Chrysophyceae	8	120	23	20
Heterokontae	1	15	1	7
Euglenophyceae	33	495	94	19
Volvocales	11	165	30	18
Chlorophyceae	30	450	66	15
Sarcodina	2	30	2	7
Mastigophora	3	45	3	7
Infusoria	10	150	12	8
Total	130		373	
Zone *C*—42 samples				
Fungi	2	84	15	18
Myxophyceae	9	378	36	10
Bacillarieae	24	1,008	264	26
Dinophyceae	3	126	20	16
Cryptophyceae	4	168	74	44
Chrysophyceae	11	462	82	18
Heterokontae	2	84	24	29
Euglenophyceae	34	1,428	374	26
Volvocales	24	1,008	204	20
Chlorophyceae	77	3,234	680	21
Sarcodina	10	420	25	6
Mastigophora	15	630	64	10
Infusoria	30	1,260	164	13
Total	245		2,026	

TABLE 3 (*contd.*)

Plankton	Number of Species Present	Theoretic Number of Occurrences	Actual Number of Occurrences	Percentage of Theoretic Occurrences
Zone *D*—7 samples				
Fungi	1	7	2	29
Myxophyceae	4	28	10	36
Bacillarieae	12	84	37	44
Dinophyceae	1	7	1	14
Cryptophyceae	2	14	7	50
Chrysophyceae	6	42	8	19
Heterokontae	2	14	4	29
Euglenophyceae	22	154	51	33
Volvocales	10	70	22	31
Chlorophyceae	46	322	132	41
Sarcodina	4	28	4	14
Mastigophora	2	14	4	29
Infusoria	11	77	22	29
Total	123		304	
Zone *E*—17 samples				
Fungi	1	17	4	24
Myxophyceae	11	187	46	25
Bacillarieae	22	374	144	39
Dinophyceae	2	34	10	29
Cryptophyceae	2	34	16	47
Chrysophyceae	4	68	15	22
Heterokontae	2	34	13	38
Euglenophyceae	28	476	130	27
Volvocales	11	187	46	25
Chlorophyceae	60	1,020	409	40
Sarcodina	5	85	9	11
Mastigophora	7	119	9	8
Infusoria	16	272	45	17
Total	171		396	

that the phosphorus either disappears or reaches a very low level in the lower part of Zone *C*, and, although figures are not available, phosphorus contributed by Indianapolis sewage probably disappears rapidly.

During the period in which the river was studied, there was little indication that any one of the five zones were grossly polluted or extremely poor in nutrient material. Table 5 shows the behavior of four plankton groups generally regarded as indicators in this respect. The Cryptophyceae usually favor a water rich in organic nutrient matter, such as would follow recent pollution. Their abundance in the stretch below Anderson is striking, as is their low occurrence above Anderson, where the Muncie sewage and wastes are most effective. They remain in high quantity to the mouth of the river, however.

Similar behavior is evident for the Chrysophyceae, but, favoring clean water as they usually do, their low numbers in the last zone are hardly explicable. The Euglenophyceae vary only slightly in average occurrence, but average numbers drop sharply in both polluted stretches. Volvocales, generally partial to rich water, remain abundant after attaining high numbers.

Two aspects of plankton distribution should not be lost sight of in this evaluation. One is that the plankton in the White River is generally very high in total numbers as compared to many streams. On Sep. 30, 1940, Hupp (*15*) found 107,493 algal cells per milliliter at Northern Beach, which is 41.7 miles below the river source. While this is an unusually high number, it will be shown that total plankton counts usually exceed 500 per milliliter, which has been taken as the minimum number of a single species constituting a bloom.

The other aspect is that there is a great fluctuation from year to year at any given point, and for any given species. Thus, in April, 1941, Hupp found about 32,000 diatoms (which are usually most abundant in spring) while in September there were about 2,000. The same dates in 1940 showed about 18,000 and 400, respectively. The whole plankton picture indicates either that a great deal of physical and chemical data should be gathered con-

TABLE 4

*Relative Occurrence of Species**

Species	Zone A	Zone B	Zone C	Zone D	Zone E
	Number per ml of Raw Water				
Cyclotella meneghiniana	20	387	716	340	1,564
Cryptomonas erosa	33	22	677	144	113
Chrysococcus rufescens	6	7	82	23	25
Euglena acus	4	2	13	1	0.5
Euglena polymorpha	30	14	35	8	3
Phacus pyrum	1	3	11	7	2

* Samples were taken on Sep. 11, 1941.

currently if an interpretation for a single year is attempted, or, if the object is to observe trends, data for 10 or more years should be gathered.

Specific causes for the plankton abundance in the White River above Indianapolis are difficult to state definitely. Some of the general causes, however, are as follows:

1. Large human population with urban wastes from Noblesville, Anderson, and Muncie, which are located directly on the river

TABLE 5

Occurrence of Certain Plankton Groups in Zones

Plankton Group	Zone A	Zone B	Zone C	Zone D	Zone E
	Avg. No. Occurrences/ml/Sample				
Cryptophyceae	2.62	2.26	1.75	1.00	0.94
Chrysophyceae	1.62	1.60	1.95	1.14	0.82
Euglenophyceae	8.25	6.02	8.90	7.20	7.64
Volvocales	2.25	2.00	4.85	3.14	2.70
	Avg. No. Organisms/ml/Sample				
Cryptophyceae	48	44	618	144	119
Chrysophyceae	17	11	96	36	26
Euglenophyceae	109	56	135	90	30
Volvocales	74	207	299	308	115

2. Large amount of drainage from agricultural and pasture lands

3. Treatment of industrial waste, making it nontoxic

4. Slight gradient, with a large number of pooled areas so that the water ages, allowing for plankton growth

5. A BOD which is generally low enough so that DO favors plankton activity (At times the oxygen has been depleted below Muncie for short periods.)

6. A pH which is usually in the life range of most organisms, with no extremes, fluctuating slightly around 8.3

7. A turbidity which is generally low.

With these major favorable factors present, the addition of one other, such as a slug of fertilizer washed from fields by a local rain, might easily cause one or more organisms to bloom and move downstream until the nutrient is exhausted. While blooms are of frequent occurrence in this river, no account is taken of them in the study, primarily because intensive sampling was not done. The standing crop of plankton is large, however, and the percentage of expected occurrence, is high for certain groups, as shown in Table 3. These groups include diatoms, cryptomonads, euglenids, and suspended nonfilamentous green algae.

Data in Tables 3 and 5 also support an idea suggested by Table 1 that the river might be termed moderately fertilized, but not polluted, except in the Muncie area at the time of the study. Table 4 shows that Euglenophyceae and Volvocales, some species of which appear to favor recent pollution, persist through all zones. The same is true, although in lesser numbers, of Cryptophyceae and Chrysophyceae which tend to die out in recently polluted waters.

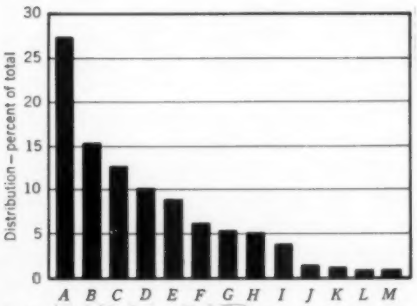

Fig. 1. Percentage Distribution of Species Among Thirteen Groups

Percentages shown are for the following: A—*Chlorophyceae;* B—*Euglenophyceae;* C—*Infusoria;* D—*Volvocales;* E—*Bacillarieae;* F—*Myxophyceae;* G—*Mastigophora;* H—*Chrysophyceae;* I—*Sarcodina;* J—*Cryptophyceae;* K—*Dinophyceae;* L—*Heterokontae; and* M—*fungi.*

In all, 305 species or genera of algae and protozoa were found, and they comprised 597,361 individuals. Figure 1 shows the percentage distribution of the thirteen groups counted. It indicates the approximate distribution, among orders, of the species one might expect to find in a stream. There are very few genera and species of Cryptophyceae, as compared with Chlorophyceae, and in this study no attempt was made to count more than four species of bacteria.

Figure 2 shows the percentage composition of the thirteen groups counted. As might be expected, the Chlorophyceae made up the largest group. It should be remembered that these numerical ratios do not indicate mass ratios; most of the Chlorophyceae are very small in mass. Cryptophyceae, despite their small number of species (six), make up the third largest number of organisms, and Euglenophyceae, with 47 species, made up only 1.5 per cent of the total numbers. The distribution of species of *Euglena* further indicates that only certain species are of use as indicators of pollution. Thus, thirteen species occurred in all five zones and thirteen species occurred in some single zone of the five. The distribution by species and numbers is shown in Table 6. Zones *B* and *C* probably contained the largest amount of substances from recent pollution, but the number of Euglenophyceae per milliter is not unduly high. The species making up most of the population, however, were *Euglena acus, Euglena gracilis, Euglena pisciformis, Euglena polymorpha, Euglena velata* and an unrecognizable species (after formalin preservation), probably *Euglena velata* again, together with *Phacus pyrum.* These are generally most abundant downstream from a source of sewage pollution.

The Euglenophyceae population decreased below Indianapolis according to expectation, but enough of them remained to justify calling the river moderately rich—a "Eutrophic stream." Further evidence of this is seen in the numbers of *Cryptomonas erosa* found per occurrence, which is shown in Table 7. This species is not tolerant of gross pollution but does favor fertilization, and its distribution and occurrence in the White River strongly sup-

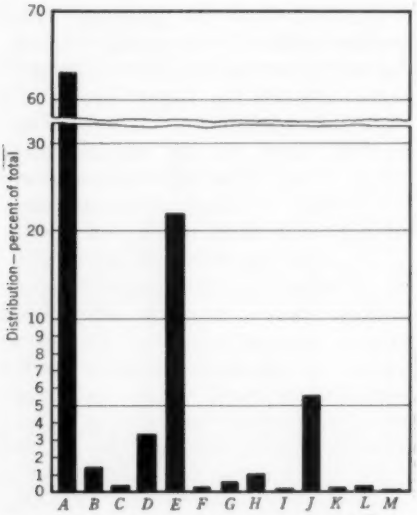

Fig. 2. Percentage Distribution of Plankton Population Among Thirteen Groups

Percentages are as follows: A—*Chlorophyceae, 63 per cent;* B—*Euglenophyceae, 1.5 per cent;* C—*Infusoria, 0.39 per cent;* D—*Volvocales, 3.3 per cent;* E—*Bacillarieae, 21.9 per cent;* F—*Myxophyceae, 0.25 per cent;* G—*Mastigophora, 0.59 per cent;* H—*Chrysophyceae, 0.59 per cent;* I—*Sarcodina, 0.04 per cent;* J—*Cryptophyceae, 5.5 per cent;* K—*Dinophyceae, 0.26 per cent;* L—*Heterokontae, 0.12 per cent; and* M—*fungi, 0.45 per cent.*

ports the characterization of the river given here.

One last indication is taken from the ciliate protozoa, of which 39 species were found. Only three of these species occurred in all zones and 21 occurred in some single zone of the five. Their average numbers per milliliter per occurrence were 3.70, 1.33, 9.71, 18.00, and 8.15 for Zones *A–E*, respectively. If these numbers, especially for Zones *D* and *E*, seem to compare favorably with those for the Euglenophyceae, it will be noted from Table 2 that the ciliate percentage of possible occurrence is consistently lower for each zone than that for Euglenophyceae—about 10 per cent lower in all zones except *D*, where it is almost 5 per cent lower. It is even more striking to compare the possible occurrence of all ciliates with the single species *Cryptomonas erosa.* This last species had for percentages of possible occurrence 100, 80, 88, 100, and 82 for Zones *A–E*, respectively. The food of *Cryptomonas* is dissolved in the water but most of the ciliates feed on bacteria. The low numbers of ciliates and the low rate of occurrence indicate low numbers of food bacteria.

The numbers of organisms per milliliter as reported above are not usually high for the White River. Abundant data are available at the canal intake to support this contention. In 1943, algae were counted on 15 days in April, 4 days in May, 10 days in August, and 19 days in September. On 10 of these 48 days, the count was below 1,000 per milliliter, the lowest being 463 on Apr. 1. The highest was 22,063 on Aug. 27. These counts bear out the earlier assertion that the river has been notable for a high plankton content. Physical and chemical data indicates a good basis for the assertion.

Physical and Chemical Effects

Turbidity determinations were made for all months of 1943 except June, July, October, and December. The highest was 64 ppm on Sep. 8 and the lowest was 0.8 ppm on Jan. 12. In January, turbidities measured 12 ppm or below, except for 5 days, and during the first 10 days of March they were 10 ppm or less. In September, they were as low as 15 ppm on one day and 25 on 4 days, but were usu-

TABLE 6

Distribution of Species Among Zones

Item	Zone *A*	Zone *B*	Zone *C*	Zone *D*	Zone *E*
No. of samples	8	15	42	7	17
No. of species	29	33	34	22	28
No. of occurrences	66	94	374	51	130
Avg no. of individuals per ml per occurrence	23.10	9.00	15.19	12.41	4.00

ally 40 or higher. Because much of this turbidity was caused by plankton, the clarity of the water was such as to favor algal production. Further evidence of this is seen in the filter runs. The average turbidity for January was 7.99 and for September it was 38.33. The average filter run for January was 34.6 hr; for September, 59.9 hr. Despite an approximate ratio of 5 to 1 for turbidity, the filter runs in September were almost twice as long between washes. The plankton in September consisted of such types as *Cryptomonas* and *Euglena*, which disintegrate readily in coagulation and filtering and do not clog the filters. Temperatures are also favorable for plankton growth from March through November. This is shown in Fig. 3, which gives the 10-year averages for temperature, DO, and BOD at the canal intake at Indianapolis for the period 1945–54. The temperatures agree quite closely with DO values, being highest when the DO is lowest. There has always been abundant oxygen in the water at the canal headgates, where there is a noticeable ponding or slack current, giving the algae an opportunity to accumulate to some extent. The BOD values actually are lower than past experience would have indicated. Many other rivers and creeks in the Ohio Valley have shown values of 4–10 ppm, despite a lack of known pollution.

The plankton content indicates a well fertilized stream. Figure 4 shows the 10-year averages for nitrates and ammonia nitrogen, also at the canal intake for the Indianapolis Water Company. Nitrates were surprisingly high, much higher than the value of 0.2 ppm which Sawyer and Lackey (*20*) estimated to be necessary for blooms (500 per milliliter of a single species) to occur. The ammonia nitrogen values are also high, but this may be due to the destruction of the bodies of microorganisms which are near the end of their life cycle. The rate of

TABLE 7

Occurrence of Cryptomonas erosa *in Five Zones*

Item	Zone *A*	Zone *B*	Zone *C*	Zone *D*	Zone *E*
No. samples	8	15	42	7	17
No. occurrences	8	12	37	7	14
Avg no. per ml per occurrence	33.13	28.17	60.72	167 66	137.57

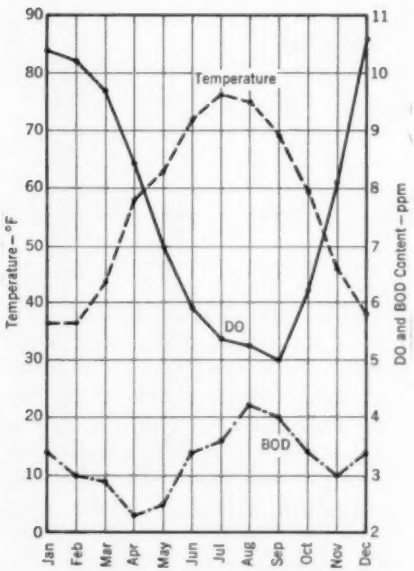

Fig. 3. Relation Between Temperature, DO, and BOD Averages for Period 1945–1954

The values shown are averages for the period 1945–1954. BOD values for 1945 and the first 8 months of 1946 are not included.

plankton decrease is high; for instance, on Sep. 4, the plankton count dropped from about 14,000 per milliliter at the headgates of the canal, to 1,000 per milliliter at the water plant intake. This decrease may have been partly caused by sampling an unmixed or partly stratified water at the headgates, where the sample used at the intake was mixed. Ordinarily, however, plankton does tend to rise rapidly to a peak and then decrease just as rapidly.

Phosphate is also necessary to plankton growth and, although 10-year averages are not available, phosphate was shown on several occasions to be high in the headwater areas and then rapidly depleted with distance downstream. Table 8 shows the amounts of phosphorus, as PO_4, found at five stations on three different dates. The phosphorus content was initially high, but it decreased rapidly until, at the canal headgates, none was detectable. If the downstream decrease was because all or a portion of the PO_4 was removed by contributing to plankton increase, then its absence a short distance above the canal headgates became a limiting factor for plankton and plankton decrease could be expected downstream until additional PO_4 became available.

TABLE 8

Phosphorus Content, as PO_4, at Five Stations

Station	Sep. 30, 1940	Oct. 21, 1940	Jul. 30, 1941
	Phosphorus Content, as PO_4—*ppm*		
Chesterfield	0.36	0.78	
Anderson	0.35	0.62	0.08
Perkinsville	0.06	0.16	0.05
Potters Bridge	0.01	0.13	trace
Canal Headgates	0.00	0.00	0.00

From the striking decrease in plankton which starts just about the end of Zone *C*, it might be expected that a decrease below Indianapolis would occur unless the city added nutrients. The river flow, as shown in Table 1, increases greatly at Indianapolis. Figure 5 shows what happens to the DO and BOD in the next 30 miles after the outfall at Indianapolis, on an averaged basis for the period 1945–55. It may be assumed that the sewage treatment plant effluent adds considerable PO_4 to the river, and Fig. 5 indicates that there is a high rate of biological activity, caused by both bacteria and plankton. The bacterial activity is

indicated by the coliform maximum, the rapid reduction in BOD, and the high percentage of possible occurrence of ciliates (*see* Table 3) which normally feed on bacteria. The plankton activity is indicated by rapid reaeration, the persistence and high percentage of occurrence of Chlorophyceae, and the high percentage of occurrence of plankton, generally. While the number of species in those in Zone *D* dropped 50 per cent (from 245 to 123), those which were present occurred frequently and abundantly. There were more blue green algae, mostly limnetic types, in Zone *E* but the numbers of Chrysophyceae, Cryptophyceae, and Euglenophyceae in Zone *E* were not very different from Zone *D*. Zone *E* generally corresponded to the lower reaches of most large streams. The stream flow had increased greatly, any food substances were correspondingly diluted, and organisms were varied. Whenever large numbers occurred, they were generally blooms of some few species.

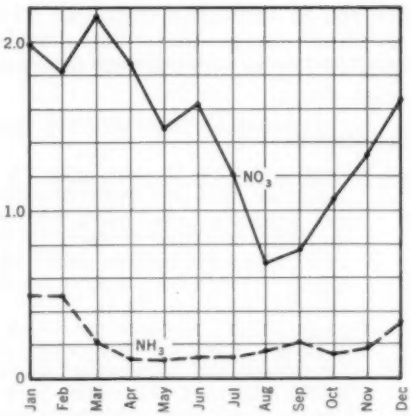

Fig. 4. Average Nitrate and Ammonia Nitrogen Contents

The sampling point was at the canal intake for the Indianapolis Water Company. Data are given in parts per million, and averages are for the period 1945–1954.

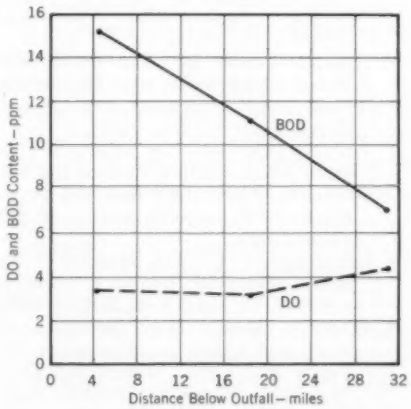

Fig. 5. Average BOD and DO Values at Three Stations

The data shown are 10-year averages for 5-day BOD and DO values at three stations below the Indianapolis sewage treatment plant outfall.

Summary

The White River illustrates very well the behavior of a large stream in a well populated, temperate-zone situation. Starting in a rich agricultural area, it soon becomes well fertilized and serves both to carry off and purify agricultural, trade, and human wastes and, at the same time, to serve as a water supply for towns and cities. Its municipalities provide for complete or partial treatment of their wastes, so that the stream does not become dangerously overloaded. But the waste treatment does not prevent heavy fertilization of the upper reaches of the river and a heavy plankton growth soon appears. This is beneficial in assisting oxidation of putrescible mat-

ter and in furthering reaeration. In the lower reaches the plankton tends to diminish, as soluble food becomes more dilute.

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Details of Distribution Reservoir Design

Duncan A. Blackburn

A paper presented on Oct. 27, 1955, at the California Section Meeting, Sacramento, Calif., by Duncan A. Blackburn, Chief Engr. and Gen. Mgr., City of Pasadena Water Dept., Pasadena, Calif.

FROM the time man first began building structures he has painfully but surely been learning to cope with the many and diverse forces of nature. The construction of satisfactory reservoirs for water supply systems has presented its full share of problems.

Domestic water reservoirs were originally unlined earth depressions without roofing. Later, they were constructed with cobblestone linings placed with mortar and were covered with flat wooden roofs. Advancement continued to be made by the use of linings of plain concrete. These linings were allowed to crack and repairs were made by pouring hot tar or asphalt over the cracks, with or without the use of an imbedded fabric. Some progress was made in roof design by the adoption of a very slightly pitched wooden structure which was covered with roofing felt. Later, roofs with steeper pitches, supported by wooden or steel trusses, were constructed. Many of these were covered with corrugated metal. During this period of progress in the construction of excavated reservoirs engineers adopted and improved upon the construction of wooden, steel, and concrete tanks for water storage purposes. In recent years more and more reservoirs have been built with reinforced concrete roofs for the sake of appearance, durability, and low maintenance cost, and often with the secondary purpose of providing playgrounds or parks on top of the reservoirs.

Along with these features engineers have progressively made improvements in the construction of reservoir subgrades and earth fill embankments. Originally the ground was accepted in its natural condition and the embankments indifferently compacted by the use of sheep. Later, compaction was obtained by horse-drawn grading equipment. The development of backfill-compacting equipment from the petrolithic or sheepfoot tampers to wobbly-wheel rollers and other types of equipment has progressed considerably in recent years. More care is now taken in controlling the moisture content of water-bound fills, and some successful work has been done in the construction of oil-bound fills such as that shown in Fig. 1. The use of soil-cement fills and subgrades for reservoir structures is becoming increasingly common. There have been a number of recent projects in which, after the subgrade was prepared, it received a treatment of catalytically blown asphalt prior to the placing of a lining. The author believes that if this treatment is used, consideration should be given to the change in the coefficient of fric-

tion between wall footings and subgrades. The designer will probably find that, in order to have a stable structure, he must provide keys at the bottom of the wall footings.

This article is primarily concerned with the placing of concrete linings and the construction of concrete slabs for distribution reservoirs. A good watertight lining must be developed because the purveyors of water, who must conserve a commodity which is becoming shorter in supply and more expensive to handle, want assurance of structural stability.

ness. Gunite-type linings of 1¼–2-in. thickness, with or without reinforcing, should be referred to as membranes, as they are not subject to jointing except around the outer perimeter.

Care should be used in the placing of gunite membranes so that each daily placement has a long taper at the edge of the work instead of a vertical surface. This prevents cold-joint cracking in the membrane. Most cracks that develop in such a membrane will be small and widely dispersed and will have a tendency to tighten when subjected to water storage.

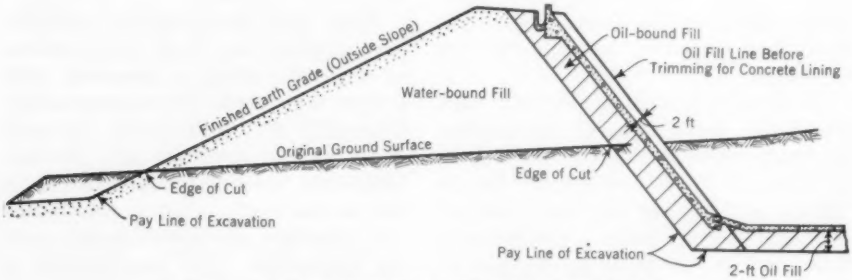

Fig. 1. Typical Section of Oil Fill Reservoir Bank

Slope of oil fill bank, horizontal to vertical, is 1.5:1. Eight feet of oil-bound fill are used on banks, 2 ft on bottom. Concrete lining is 6 in. thick.

Checkerboard Pouring

Over the years, a method of pouring concrete linings by the use of the "checkerboard" system of panel construction has been developed. Alternate panels, usually limited to an area of approximately 400 ft, are placed and allowed several days in which to shrink before adjacent panels are poured. This assists in obtaining a tighter joint.

In referring to "jointed concrete linings," the author means those linings which are 4 in. or more in thick-

In recent years the size of checkerboard pours has been increased to as much as 40 × 60 ft, requiring a corresponding increase in the amount of reinforcing steel used in the concrete slabs in order to minimize cracking. This has not always been successful. The author believes that checkerboard pours are often constructed in such excessive sizes that the concrete and steel cannot successfully perform their desired functions because of a large buildup of subgrade friction. A member of the Portland Cement Association has recently observed that con-

crete slabs without reinforcing may be poured with consistently satisfactory results if each pour is limited to an area 10 ft square. Another objection to large slabs is that there are generally several large columns located within a panel. This increases the likelihood of cracks developing within the slabs, particularly if the footings for these columns are poured monolithically with the slab. Footings for such columns should preferably be poured independently of the lining and should have joints provided around the columns or column footings. The joints should, of course, be provided with a flexible seal. When floor and footings are poured monolithically there is a concentration of shrinkage in the abrupt change of cross section at the perimeter of the footings. Regardless of any sloping of the footings, these stresses are concentrated to abnormal unit values at the junction of the footing and floor. Extra reinforcement at the junction is of doubtful value. With the use of extra steel the shrinkage cracks tend to increase in number, but decrease in size. A definite contraction joint would seem to be more desirable, as it provides better control of the shrinkage. Also, a definite joint around the perimeter of a footing seems to be advisable in order to eliminate stresses caused by unequal settlement of the footing and the adjacent floor slab. Regardless of how large a column footing is made, it will always have to carry its own dead load, plus the superimposed water load equal to that carried by the floor slab, plus the entire load on the column.

Joint Spacing

In considering the spacing of construction and expansion-contraction joints in the lining, the designer must realize that there is a resistance to horizontal movement of the slab. This resistance is caused by subgrade friction against the bottom of the loaded slab and limits the effective spacing of joints. If this is ignored, cracks are apt to occur between the joints because of frictional resistance exceeding the tensile strength of the slab. (The author refers primarily to the shrinkage which takes place in the very early life of the slab). If the lining is kept covered with water at normal temperatures, shrinkage stresses are at a minimum. Most shrinkage cracks occur prior to putting a reservoir into service. Expansion-contraction joints should preferably extend continuously through the entire length of the structure instead of coming to a dead end at some arbitrary point. Acute angles where joints meet should likewise be avoided. The designer should realize that in addition to stresses caused by shrinkage and temperature change, there are also those caused by the swelling of concrete when it is subjected to water under pressure. If no provision is made for shrinkage, temperature change, or swelling, damage to the lining is likely to occur. It should be borne in mind that a reservoir may be out of service for some time while being repaired and that stresses may develop which were not contemplated at the time the design was made.

A desirable feature of a good joint in the concrete lining of a reservoir is the horizontal offsetting of the vertical face of the joint. This offsetting should normally be located midway between the top and bottom surfaces of the slab. If the face of the joint is not offset but is carried straight through the lining, the edges of the adjacent panels should be set upon

a common secondary panel, approximately 16–18 in. wide, with a steel-troweled surface. The secondary slab provides a backing for the joint, allows for movement of the slabs, and eliminates the need for the use of steel dowels to prevent unequal settlement of adjacent panels. The upper half (at least) of the joint should be wedge-shaped and somewhat wider than the space created by the shrinkage of the concrete during the curing process. This wedge-shaped area should be filled with some type of mastic even though there may be a water stop across the joint.

One of the most important operations is the placement of the concrete at the construction and expansion-contraction joints. It is vital that there be no entrained air or water pockets in the concrete adjacent to the joints. Usually, the primary pours do not give much trouble because the forms may be easily vibrated, but with the secondary pours, this is not always true. During the past 30 years there have been tremendous improvements in equipment used to consolidate concrete but the author believes that a tool, such as a vibrating spade, could be developed to assist consolidation at joints. Proper consolidation is also hindered when reinforcing steel or dowel bars are placed close to or through a joint.

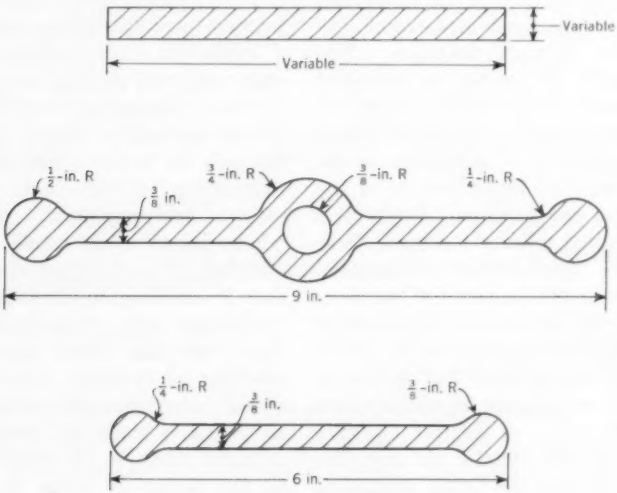

Fig. 2. Rubber Waterstops

Types shown are those referred to in this article as, from top to bottom, A, B, and C.

Waterstops

One of the older types of waterstops used across expansion-contraction joints is the copper pan. In recent years several other types have been developed. Prominent among these are Type A, B, and C rubber stops (*see* Fig. 2) and polyvinyl plastic stops

in "flexstrip," "cellular" and "labyrinth" shapes, all of which are available in long premolded or extruded strips. Latex-asphaltic materials and, more recently, thiokol rubber compounds have been used as joint fillers and seals. In this article they are also classed as waterstops. In using these types of stops, care should be exercised to prevent losing the full shear value of concrete-keyed joints, and provision should be made to protect the stops from damage caused by shear in joints which have lateral movement, such as those at the bottom of the wall of a prestressed tank.

It is possible to construct a good expansion-contraction joint in reservoir lining without the use of preformed waterstops provided the joints are properly backed up by the previously mentioned narrow secondary concrete slab and provided the joint in the primary slab is filled with a hot pour of latex-asphalt mixture. This has been accomplished to the extent that subdrains under the lining have successfully been eliminated.

When this type of joint is used, added security may be obtained by making the subgrade as watertight as possible. An oil-bound fill under the lining has successfully provided this requirement. The City of Pasadena Water Department has two cut-and-fill type reservoirs with oil-bound fill subgrades (*see* Fig. 1). The oldest of these reservoirs was constructed 25 years ago and only one of them was constructed with subdrains under the lining. Leakage from both is negligible. Questions have frequently been asked about the danger of uplift at the time of emptying a reservoir having such joints and no subdrains. There have been no indications of uplift on the linings of either of these structures and the joints are believed to be very tight.

Copper waterstops continue to be popular with some engineers but a word of caution should be given concerning their usage. All bends in a copper pan, and particularly in the bellows, should be curved, rather than abrupt. Curved bends assist in preventing concentration of stresses and resultant failures at a later date. Care should be exercised when using sharp tools near copper sheeting. This material is easily punctured and, if damaged, should be marked for immediate repair.

In recent years, engineers have witnessed the introduction of one of the most successful additions to the family of waterstop materials. This is a preformed rubber waterstop which is made in three shapes and is often referred to as the "dumbbell" type (*see* Fig. 2). Figures 3 and 4 show typical connections and installations of this type of waterstop which can, with the use of intersection fittings and vulcanization, be made into a continuous web for the entire lining system. It does, however, present some problems. The surface of the material is very smooth and does not offer an appreciable amount of bond to concrete. If there is a flaw in the concrete under

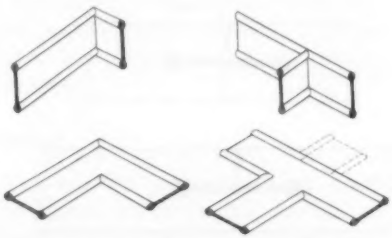

Fig. 3. Typical Rubber Waterstop Connections

the stop, the flexibility of the rubber and its lack of bond with the concrete will cause the rubber to be depressed by the water pressure and thereby permit a leak around the material. In order to assist in the prevention of this type of failure, the manufacturer or contractor could be required to roughen the surface of the rubber. This would give it a "tooth" and would provide a greater bond to the concrete than is now available. This type of stop can be purchased in two forms, molded and extruded. Some engineers have stated that the extruded form is difficult to keep lined up in the work because it has a tendency to warp and wind out of position. The extruded material is covered with a wax-like substance from the extrusion process. The removal of this substance by the manufacturer would materially improve the bonding characteristics of the rubber.

The polyvinyl plastic waterstops appear to answer some of the designer's problems. They are manufactured in three general types—flexstrip, cellular, and labyrinth (*see* Fig. 5). This material, too, can be formed into a continuous web by welding the pieces together. The material, after being in a molten state, returns to its original condition when cool. Again, as in the use of other waterstops, consolidation of the concrete around the material is highly important. Two typical installations are shown in Fig. 6.

Hot-poured latex-asphalt compound was included as a waterstop material because it has been successfully employed as a filler in V joints. It is poured in a liquid state and fills all of the small faults in the joint. The material should be backed up by some suitable means for preventing cold flow. This can be accomplished by the use of an offset joint or a narrow secondary slab as previously described. Latex-asphalt may be placed in a joint without priming and the concrete may even be slightly damp at the time of application. Excess dust in a joint may prevent a satisfactory bond. The Pasadena Water Department was the first on the Pacific Coast to use this

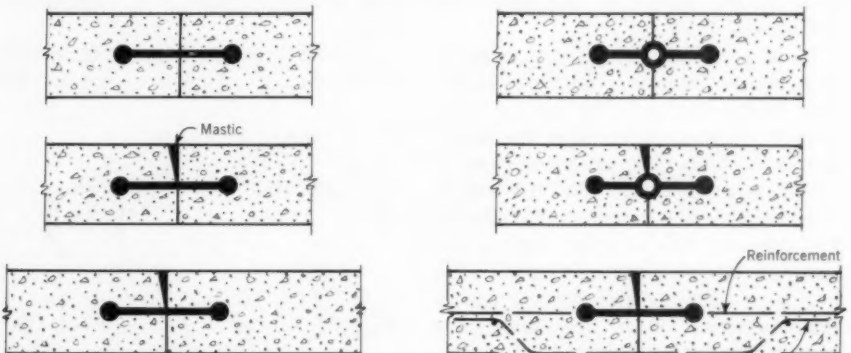

Fig. 4. Typical Rubber Waterstop Installations

material for joints in water reservoir construction. At that time the product contained a filler of inert mica. The filler made it possible to pour the usually troublesome joints on the side slopes of reservoir linings without great difficulty. The inclusion of the mica filler provided, in the author's opinion, a better material for this purpose than today's product in which there is no such filler.

Thiokol is a new product which has recently been used for sealing cracks in concrete linings. It may also prove to be a very desirable sealant for joints. Thiokol is a synthetic rubber which requires no heating. The product is supplied in two forms, one of which has a low viscosity and is pourable material. The other form has a high viscosity, is nonsagging, and is useful for application by calking gun or spatula to vertical or overhead joints where flow is undesirable. Both forms require mixture with an accelerator and, at room temperature, they cure to a firm, solid rubber. They should be used with their specific primer. Thiokol seems to have excellent properties for bridging cracks in concrete linings. Before priming the concrete it must be cleaned and made free of foreign matter. Sandblasting has been successfully used for this purpose. The material has been used to fill cracks which have been slightly widened for a depth of $\frac{3}{4}$ in., and will withstand a large amount of expansion and contraction.

So far, consideration has been given to linings of Portland cement only. The increased use of asphaltic concrete as a reservoir lining must not be overlooked. There have been a number of reservoirs in which this material has been used and several of these have presented problems in the control of excessive leakage. It should be remembered that asphaltic concrete makes a relatively pervious lining and that in order to obtain the best results, an impervious subgrade should be provided. It is believed that excellent results can be obtained if an impervious oil-bound subgrade is provided for this material.

Some work has been done in the construction of reservoirs with soil-cement bottoms and reinforced concrete sides. There is some doubt about the general acceptance, by water works operators, of soil-cement bottoms for distribution reservoirs. Difficulties may be encountered in cleaning such lining satisfactorily. Ultimate wearing of the surface of the bottom lining may occur to the extent that good drainage cannot be maintained during cleaning operations.

Roofing

The need for placing roofs on water distribution reservoirs has become increasingly apparent in the water works industry. A good roof should provide protection against sunlight and the resultant growth of algae and it should protect the water in storage from evaporation and from contamination by outside sources.

In selecting a type of roof to be used, the economics of the proposed construction should be considered. First cost should be balanced against life expectancy and maintenance costs. Various types of roofs may not be adaptable to the structure to be covered. The original type of wood-sheeted roof is today considered undesirable. It had little effect other than that of a shield to protect the stored water from the effects of sun-

light, and provided very little protection against rain or outside contamination. Structures covered with composition roofing materials afford better protection from contamination. Flat roofs are, however, difficult to design against wind uplift over large areas unless bracing is placed below the water level in the reservoir. An inexpensive and easily maintained type of construction is one in which a sloped covering of corrugated metal is supported by wooden or steel purlins, screw nails instead of the early lead head nails. It has been found that expansion and contraction of the corrugated metal plus wind uplift against the metal sheeting invariably lifted the lead head nails out of the supporting members, whereas drive screw nails continued to have good holding power.

Because steel tanks are relatively small in roof area, a rather flat wooden roof covered with roofing felt, or a steel roof, may be used. During recent years numerous concrete dome shells

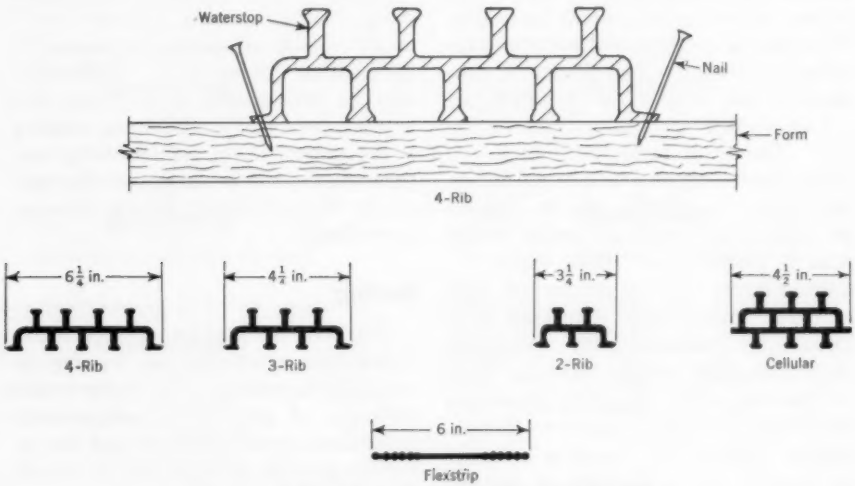

Fig. 5. Labyrinth Waterstops (Polyvinyl Plastic)

trusses, and columns. Sound and economical construction with very low maintenance costs have been obtained by using galvanized corrugated metal sheets placed on treated Douglas fir or redwood purlins and trusses and by using redwood columns and galvanized steel connectors.

The types of nails used for securing metal roof coverings have improved immensely during the past several years. The main development has been the use of case-hardened drive

have been used as coverings for prestressed concrete tank reservoirs.

Many innovations have been made during the past few years in the construction of concrete roofs for reservoirs. There is an apparent increase in the use of concrete for reservoir coverings. It is usually true that a concrete slab roof is the most expensive in first cost, but if properly constructed, it will have very low maintenance costs. The use of concrete roofs is becoming increasingly important

and desirable in Southern California. This is due largely to the rapidity with which areas are becoming heavily populated. Surrounding neighborhoods require structures that are pleasing in appearance and which have roofs that may be used for parks and playgrounds.

When a roof slab is to be poured in place, considerable care should be used in its construction. An earth blanket should be provided to keep the temperature of the concrete as even as possible. As soon as possible after a panel has been poured and finished and prior to placement of an earth blanket it should be given an asphalt coating on the upper surface. The coating is needed in order to prevent outside waters from seeping through the roof slab and contaminating the stored water. As soon as the asphalt coating ceases to be tacky, it should be covered with a thin layer of earth which should be puddled with water until the entire roof is constructed. After the complete roof has been placed and cured it may then be covered with a permanent earth blanket. Water stops should, of course, be placed between adjacent panels.

There has been considerable development of various types of precast concrete roofs. Their use has generally proven to be satisfactory but due consideration has not always been given to expansion and contraction forces. The author recently observed an uncovered precast concrete roof which showed promise of giving the owner considerable trouble. There probably is no doubt that the precast slab was properly designed; however, the roof carried no earth blanket to aid in keeping the temperatures constant and thus was subject to extreme air temperatures and direct rays from the sun. Provision has not been made for expansion and contraction. As a result of these conditions, the grouting between the precast units was being crushed and the center of the roof was damaged to such an extent that failure may soon occur—all because no mastic-filled or other suitable expansion joint had been provided. The result is a roof which will not be much tighter against rainwater than the old-style flat roofs made of 1 × 12-in. wooden sheeting.

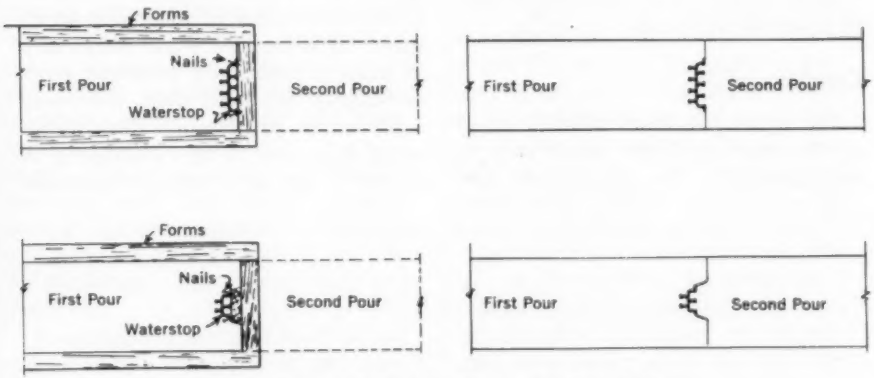

Fig. 6. Typical Labyrinth Waterstop Installations

Ventilation should be provided for all reservoirs. The greatest amount is required for roofs constructed of untreated Douglas fir. In order to keep the moisture content of wood cells below that which produces fungus rot, untreated Douglas fir should be used in well ventilated structures only. Elsewhere, treated Douglas fir or redwood should be used in wooden structures. Steel frames require less ventilation, and concrete roofs the least. A lack of sufficient ventilation may cause deterioration of mechanical equipment or painted surfaces so situated as to be subject to wetting by the condensation of evaporated storage.

Conclusions

No effort has been made to cover all the many problems which may be encountered in the design and construction of distribution reservoirs. Instead, emphasis has been directed toward the necessity of building these structures in a manner that will permit them to "breathe" structurally and atmospherically and of keeping leakage losses to a minimum. During recent years there have been constructed a number of reservoirs which failed or in which the leakage rate was entirely too great. In many of these, the blame for the failure or leakage was placed on the shoulders of the contractor when in reality it was due to faulty design or to a lack of consideration for all of the factors which are involved in the construction of watertight structures. It is time for water works men to analyze their own problems more thoroughly in order that they may build better structures. And, as always, it is wise to be conservative in the use of new and unproved methods.

Remote Control of Small Water Systems With Voice Frequency Carrier Equipment

M. W. Baty

A contribution to the Journal by M. W. Baty, Development Engr., Motorola Communications & Electronics, Inc., Chicago, Ill.

WITH the growing trend toward remotely controlled installations, centralized dispatching, and automation in many branches of industry, it is becoming increasingly important to utilize all communication facilities to the fullest possible extent. Voice messages, control signals, and data-reporting signals must all be accommodated. Control of remote installations demands rapid and reliable performance of the communication equipment, not only for efficient control but also for protection of the capital equipment controlled.

Modern communication systems may consist of any or several of such communication media as microwave, wire lines, radio, and carrier. The factor common to all these media is the use of audio tones. To make the fullest possible use of communication facilities, it becomes necessary to combine as many signals as possible over one communication channel, making the greatest use of the bandwidth available. Voice frequency carrier is a practical method of optimizing use of a voice frequency channel.*

Voice frequency carrier equipment is particularly well suited for the remote control and supervision of small water systems. By using the non-critical upper portion of the voice frequency spectrum—2,400–3,100 cycles per second (cps)—up to five voice frequency channels can be combined with voice signals on a voice frequency circuit without mutual interaction. These control channels can occupy the same audio channel as voice conversation, simultaneously and independently. Up to eight channels can be accommodated by restricting the voice signals to 1,800 cps. If the entire audio spectrum is available for voice frequency carrier, a total of eighteen channels can be combined on a single voice circuit. The use of eighteen channels, however, is somewhat in excess of the capacity of a small system, and regular supervisory control equipment is indicated for such a large number of functions. From the standpoint of cost, the point at which voice frequency carrier is no longer more efficient than supervisory-control equipment occurs when about six functions are to be controlled and supervised. The author, however, would be inclined to use voice frequency carrier channels for as many as seven or eight functions because of the simple, trouble-free operation and ease of maintenance of the voice frequency carrier equipment.

* All voice frequency carrier equipment described in this paper is manufactured by Motorola Inc., Chicago, Ill.

Small-System Application

For purposes of illustration, the remote control and supervision of three well pumps and two booster pumps in a location some distance from the well pumps will be described. The remote control is accomplished by means of five outgoing channels of voice frequency carrier. Two types of equipment are available for this application: one sends a continuous signal, the other a momentary signal. The latter type was specifically designed to operate motor starters that require momentary contact closures for starting and momentary contact breaks for stopping. The contacts of the remote-control equipment are completely compatible with the local-control pushbuttons, and pump control can be accomplished from the remote-control site or from the local station. In fact, the start-stop pushbutton box on the remote-control equipment can be exactly the same kind as that used for local pump control, a factor which is especially important when nontechnical personnel is employed.

The equipment required at the controlling end would be a power supply and three dual-channel voice frequency carrier transmitters. One of the dual-channel transmitters would be equipped with a blank channel, making a total of five control channels. Each transmitter chassis contains two carrier channels. The frequency-determining elements are encased in plug-in assemblies, permitting use of the same basic chassis on any channel. Each dual-channel transmitter chassis contains four tubes (two per channel). All tubes are of the same type, and pre-aged tubes are used for high reliability. The frequency-determining elements are all factory adjusted and the only adjustment control needed on the transmitter is the output control. A block diagram of the transmitter is shown in Fig. 1.

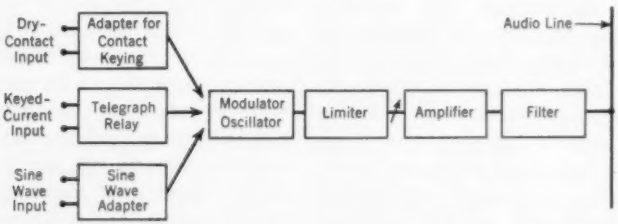

Fig. 1. Block Diagram of Voice Frequency Carrier Transmitter

One of the three input adapters is used, depending on the end device. Dry-contact input is used for pump control and some types of telemetering transmitters; keyed current for teletype equipment; and sine wave input for other types of telemetering transmitters. The only control needed on the transmitter is the output control located between the limiter and the amplifier.

All voice frequency carrier units (transmitters, receivers, and power supplies) are packaged on a chassis for mounting on a standard 19-in. relay rack or cabinet as shown in Fig. 2 and occupy two rack units of space.

This is a chassis about 17 in. long and 3½ in. wide with a 1-in. mounting flange at each end. Although designed for rack mounting, these units may be screwed to the wall or mounted in small protective enclosures.

At the booster pump station, a power supply and one dual-channel receiver would be used. At the wells, a power supply and two dual-channel receivers —one with a blank channel—would be used.

Like the transmitter, the receiver is a dual-channel unit with interchangeable frequency-determining elements that are factory adjusted. Four tubes are used for each channel, and as in the transmitter, pre-aged tubes are supplied for greater reliability. A block diagram of the receiver is shown in Fig. 3.

With the transmitters at the control station and the receivers at the booster pump station and the well pump station, there now exists a remote-control system that will enable an operator to start or stop any of the five pumps as required. The next step is to provide supervision of the operation of the pumps, which can be as simple as observing the flow or pressure in the pipeline coming from the wells. This procedure, however, may be impractical, in which event a higher degree of supervision—such as reporting back information that motor circuits are energized—will be necessary. This can be accomplished by means of voice frequency carrier equipment transmitting back to the control station to operate red or green lights on the push-button station to indicate whether the motors are on or off. This requires three transmitting channels from the well pump station and two from the booster pump station. At each station, the additional equipment would use the same power supply as the control channels and would be connected to the system by merely plugging the receiver and transmitter interchassis connectors together.

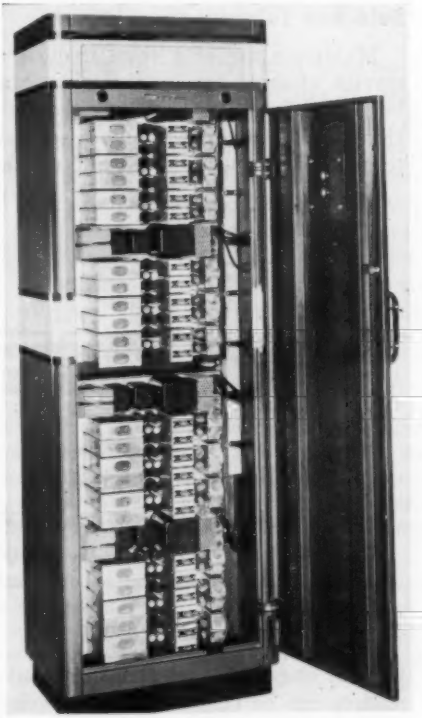

Fig. 2. Voice Frequency Carrier Unit (Transmitter)

The cabinet houses nine dual-channel transmitters, thus utilizing all eighteen voice frequency carrier channels. In appearance the receivers are the same as the transmitters and plug together one below the other in the same manner. Transmitters and receivers may be plugged together on the same power supply. One power supply will handle five dual-channel chassis.

If it is ever desired to add telemetering equipment to the remote station for quantitatively indicating well operation, the on-off supervision channels may easily be converted to carry the telemetering signals instead of the on-off functions.

Selective Telemetering

Maximum use of a voice frequency carrier channel for telemetering can be accomplished by switching the carrier transmitter input to any of several telemetering transmitters. For example, any one of nine telemetering transmitters can be connected to one voice frequency carrier channel. This is done by using two outgoing control channels of the pump control type, having three frequency operations. The net result is the use of three carrier channels to telemeter nine different readings selectively.

Because of the building-block arrangment of voice frequency carrier equipment, it would be possible to equip such a system by steps. The first would be to install remote control of the pumps. Later, a single check-back channel could be added to telemeter pressure or flow data. If incremental pressure or flow could be detected as each pump was switched on or off, this would be sufficient to supervise pump operation. Otherwise additional check-back channels could be added to supervise each pump.

As presented, voice frequency carrier signals for the control and supervision of a small system could best be transmitted over wire lines. Where all the remote equipment is grouped near one location, however, it may be well to consider the use of ultrahigh-frequency (uhf) radio as a transmission medium. The voice frequency carrier signals for control and supervision can be transmitted over a duplex uhf channel utilizing 960-megacycle (mc) equipment. This could provide four other voice channels in addition to the channel used for control, supervision, and telemetering. The base station equipment, including the antennas, represents an investment that could best be justified in large-system opera-

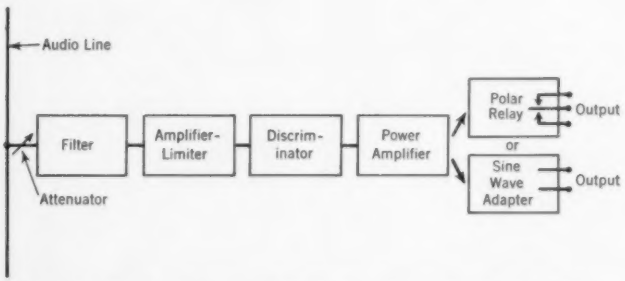

Fig. 3. Block Diagram of Voice Frequency Carrier Receiver

The polar output relay would be used for pump motor control. The only control on the receiver is the input control between the line and the filter.

tion. If an extensive expansion program is planned, 960-mc equipment should be considered.

If a very high-frequency (vhf) mobile communication system is presently being used for dispatching service trucks or cars, it would be possible to add a remote radio station at the well pump location to receive voice frequency carrier control signals transmitted from the dispatcher's vhf radio station. A special squelch receiver will prevent the control equipment from false operation when signals are picked up from mobile units talking to the dispatcher. The pump station can be set up to report back by radio when queried from the dispatching station, or it can be made to report automatically at timed intervals after first checking to see if the channel is clear. Needless to say, this application is somewhat more complicated than applying control signals to a wire line, but it is a possibility that should not be overlooked—especially if the cost of wire line facilities is high and the quality of the line is low.

Several installations have been made in which water level readings are telemetered to a dispatching station by vhf radio. In one of these, snow levels are reported from an isolated mountain location by vhf radio. Both the query method and the timer method of sending have been used. These telemetering stations operated on vhf frequencies assigned specifically for the operation.

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Accidental Pollution of North Carolina Water Supply by Octyl Alcohol

F. Rodwell Blaisdell

A paper presented on Nov. 15, 1955, at the North Carolina Section Meeting, Winston-Salem, N.C., by F. Rodwell Blaisdell, Dist. Engr., North Carolina State Board of Health, Asheville, N.C.

ON the evening of Jul. 27, 1955, a railroad tank car containing octyl alcohol was wrecked in a train accident within the city limits of Gastonia, N.C. Approximately 8,000 gal of the alcohol was spilled and it eventually found its way through a storm sewer to Long Creek and the South Fork River, polluting the water supplies of the National Weaving Company's Beaunit Mill and village, and the Burlington Mill and village at Cramerton.

According to Dr. Herbert E. Stokinger, Chief of Toxicological Services, Public Health Service:

> Octyl alcohol is a generic term that includes a number of isomeric alcohols of which 2-ethyl hexanol and isooctyl alcohol are industrially the most common. Most of these alcohols are insoluble in water; 2-ethyl hexanol is very slightly soluble. As far as toxicity information on these alcohols exists, they resemble each other closely (*1*): they have a rather high toxicity via the cutaneous route, an acute oral toxicity of moderate to slight, and an inhalation toxicity of moderate degree for small animals. Paralysis in fish occurs rapidly at low concentrations; primary octyl alcohol produces paralysis in 15 min at 67 ppm.

Pollution Discovered

The first indication of pollution of the South Fork River from this spill was when Martin Ericson, Senior Public Health Engineer of the Gaston County Health Department, received a call at 8:15 AM on Jul. 29 from the operator of the Beaunit Mill filter plant, saying that he was experiencing a terrific odor problem in his water supply. The manner in which Ericson handled the emergency is commendable, and, in the opinion of the author, his course of action will serve as a valuable example to others in the water treatment field when faced with a similar situation.

On being advised of the situation at the Beaunit Mill, Ericson immediately made arrangements with Gastonia to supply the mill with several bags of activated carbon and requested the operator to rig an improvised feeder. The Cramerton water filtration plant, whose source of supply was also the South Fork River, was alerted for trouble.

It soon became obvious that activated carbon was not going to be a satisfactory solution to the problem. Upon investigating conditions at the river, it was found that there had been an extremely heavy fish kill, and there was immediate concern as to the question of toxicity to humans. A check was made with the Southern Railway System and it was determined that the tank car had contained octyl alcohol.

Use Prohibited

A call was placed to the Sanitary Engineering Division of the State Board of Health, advising it as to what had occurred, and reporting that the water supplies at Beaunit Mill and Cramerton were involved. The opinion of the State Laboratory of Hygiene was solicited as to the toxicity of the alcohol, and the assistance of a state engineer was requested in handling the situation. J. M. Jarrett, Chief Engineer of the Sanitary Engineering Division, advised against use of the water from either supply until the toxicity could be determined. Since the regular district engineer covering Gaston County was out of the state, J. S. Ameen was dispatched from Greensboro to assist Ericson.

A public address system was obtained from the county health department and was used at the Beaunit Mill village and the Cramerton village to inform the people not to use the water. By this time the water in both systems had a distinctive odor.

Source of Supply Changes

Arrangements were made at the Beaunit Mill to connect to the Lowell water system by means of fire hose laid between two hydrants. As soon as the connection was made the work of flushing the mill system with water from the Lowell system began. This continued until the water in the system was odor-free, at which time the consumers were advised that it was safe to use the water in the system. Meanwhile, the State Laboratory of Hygiene had advised that if odor was discernible in the water it should be considered toxic. After receiving this advice, the presence or absence of aromatic odor in the water was used as a simple test to determine potability of the water.

At the Cramerton filter plant, work was underway to switch from South Fork River to the old raw-water supply, which had been Duharts Creek. This was complicated by the fact that the raw-water pumps on Duharts Creek had been removed. These were quickly replaced and work was begun to drain and flush the filter plant, storage tanks, and system. By noon of Jul. 30, the clear well was filled with odor-free water and a flushing program was started to clean the distribution mains thoroughly. At 9 AM on Jul. 31 the water in the distribution system at Cramerton was adjudged safe and the consumers advised that they might use it.

Final Precautions

Attention was then given to removal of the dead fish from Long Creek and South Fork River. The Gastonia and Mt. Holly life-saving crews volunteered to undertake this chore and the responsibility for "Operation Stink" was delegated to them. As requested, the Southern Railway System stripped the location of the spill of saturated earth as insurance against additional alcohol being washed into the creek and river during rains.

On Aug. 3 a heavy shower in the afternoon helped in flushing the storm drain and Long Creek. By Aug. 5, 1 week after the alcohol had been noted at the Beaunit Mill filter plant, the South Fork River was judged to be free of alcohol. Both communities were advised that they could use the river as a source of raw water but that careful supervision was necessary and operations should be discontinued immediately if odor was noted in the raw water.

Conclusion

The lesson to be learned from this incident is that prompt action is necessary to safeguard the consumer. If there is any question as to the cause of a taste or odor, then use of the water must be prohibited. Every effort must be made to determine the identity of the pollutant and steps should be taken immediately to safeguard the user if the water is judged to be toxic. The prompt action by Ericson, Ameen, and the officials of the two communities in this situation undoubtedly prevented sickness and possible fatalities among people using the water.

Reference

1. NELSON, N. Solvent Toxicity With Reference to Certain Octyl Alcohols and Dioxanes. *Med. Bul. Stand. Oil Co. N.J.* **11**:226 (1951).

AWWA By-Laws Amended—Affiliate Grade to Be Dropped

The AWWA Board of Directors approved as of Apr. 12, 1956, a General Policy Committee recommendation to discontinue Affiliate Membership at the end of 1956. The committee stated: "It is felt that neither the individual Affiliates nor the Association benefits by the continuation of this designation. Members do not get enough issues of the JOURNAL [they receive only four a year] to give them a continuing contact with the thinking of the water works industry."

The 42 current Affiliates may, if they wish, retain their present status for the remainder of 1956, after which they can convert their membership to the Active grade.

As a result of the Board's action, the following changes are required in the By-Laws:

1. *Article I, Sec. 1:* delete the words, "and Affiliates."
2. *Article I, Sec. 8:* delete the entire section; Sec. 9 becomes Sec. 8.
3. *Article II, Sec. 2.1:* delete the words, "and for the Affiliate grade," from the first sentence.
4. *Article II, Sec. 2.3:* delete the entire section.
5. *Article III, Sec. 1:* delete the words, "and Affiliate."
6. *Article III, Sec. 4.2:* delete the entire section.
7. *Article III, Sec. 6:* delete the words, "and Affiliates."

Standby Power for Pumping Stations

R. E. L. Johnson

A paper presented on Oct. 19, 1955, at the Southwest Section Meeting, San Antonio, Tex., by R. E. L. Johnson, Project Engr., Freese, Nichols & Turner, Cons. Engrs., Houston, Tex.

ONE of the major requirements of a municipal water system is that it be reliable and not subject to interruption of pressure or quantity. This reliability must obtain in all parts of the system, from the source of supply to the ultimate consumer.

Full gravity systems, with a source of supply and treatment works on an elevated site, and with only a transmission main and distribution system, will not be considered here. Nor will a discussion be made of plants using steam or water power. Only those installations powered by electric power generated at some distant point and transmitted to the water plant installation over overhead lines will be considered.

The reliability of the power source and transmission lines is based on its degree of exposure to earthquakes, tornados, hurricanes, cyclones, blizzards, ice storms, and floods. Each system or installation should be carefully analyzed for the possible outage of the electric power and the proper allowance must be made for probability of outage and the outage duration. Because there are innumerable combinations of circumstances affecting the reliability of power, it will be assumed, for the purposes of this discussion, that a complete outage of the normal electric power could exist for an extended period.

Meeting Demands

A municipal water system normally serves a dual function: [1] it serves water for domestic, commercial, and industrial use, and [2] it serves water for fire-fighting purposes. The largest demand on most systems is the required flow for fire fighting, and, if this can be met, the domestic load can be met. In a town with a population of 10,000 persons, the normal peak day domestic usage would probably not exceed 1½ mgd, or an average rate of about 1,000 gpm. The required fire flow, according to the standard schedule for grading cities and towns by the National Board of Fire Underwriters (*1*) for a town of 10,000, is 3,000 gpm for a period of 10 hr. This fire flow is in addition to the peak daily domestic demand, making a total flow of about 4,000 gpm. This would be about double the peak hour domestic demand. In the larger cities, with populations of 200,000 and a peak daily demand of 30 mgd, or 20,000 gpm, the fire flow is 12,000 gpm, making a total demand of 32,000 gpm for 10 hr. The peak hourly domestic demand would probably not exceed about 28,000 gpm. This shows that the ratio of fire flow to domestic peak demand decreases as the city grows larger. In other words, it is more difficult for the small city to meet these demands than it is for the larger city.

These peak demands can be met by direct pumping from wells or treatment plant, by elevated storage alone, or by a combination of storage and reliable pump capacity. If the entire peak demand is to be met by direct

pumping from the source, the treatment works or wells and distribution pumps would have to be of sufficient capacity with reliable power at all points to meet this demand, or, if the entire demand is to be met by elevated storage, the elevated storage tank or tanks would have to have a capacity to meet the demand for 4–10 hr, depending on the size of the city. Obviously, neither of these extremes is the answer because, in towns of 10,000 population, the water system would have to have a firm capacity of almost four times its peak day demand, or else would have to have elevated storage in the amount of 2.4 mil gal, or 240 gal per capita. In a town of 200,000, the water system would need a firm capacity which was half again as large as its peak day demand, requiring elevated storage in the amount of 19 mil gal, or about 95 gal per capita. The answer, then, lies in a combination of storage and reliable pumping capacity. Because storage lessens the requirements on those parts of the system through which the supply has passed, ground storage of sufficient capacity, when coupled with the firm capacity of the supply to meet the above demands, must be provided.

The actual combination of the amounts of storage and reliable pumping capacity must be analyzed for each individual situation, taking into account the possibility of transmission and distribution main breaks or other failures of the system. In some instances, such as in Galveston, Tex., the source of supply is at a great distance from the city, thus requiring considerable storage within the city because of the unreliability of the single supply main. Galveston is also in the hurricane belt and is subject to power outage during hurricane periods. It must therefore depend upon auxiliary power for extended periods. In Houston, most of the supply is from wells scattered throughout the city, with several major distribution pumping stations with a multiple-feed network from several power plants located within or near the city. Thus, Houston requires proportionately a lesser amount of storage than Galveston. Even though there is a possibility of loss of any one of the major stations in Houston, the city would not be without water because the other stations would supply some water to the area normally served by the station that was out. There is no doubt that some of the cities on the eastern seaboard could have used additional storage and standby power during the 1955 hurricane season.

Power Units

In selecting the auxiliary or standby power, there are two general types from which to choose: engine-generator sets and individual engines directly connected to the pump or mechanism to be driven.

Generally, the engine-generator type is considered the more flexible, particularly when a multiplicity of small units is to be operated, such as would be found in a water treatment plant. If the treatment plant and the distribution pump station are together and are both dependent upon the same generator, it would probably be more economical to install individual units on the larger pumps and a generator set for the small units and lights. If well motors are also to be operated from the generator and at a considerable distance from the station, the power lines should be underground and not subject to failure. One must be very careful in sizing an engine generator and selecting the motors to be used with it. The normal induction motor which starts at full voltage has an inrush current of about six times its running current and

the generator must be capable of taking this shock load. Wound-rotor motors or reduced-voltage starting can be used very satisfactorily and will materially reduce the starting load. The number of pumps can also be reduced by using wound-rotor motors because the capacity of the pump is in proportion to the speed. By varying the speed of the pumps, the full range of demands on the station can be met better than they could be met by fixed-speed pumps. The inrush current of a wound-rotor motor is half again as great as the running current. Reduced-voltage starting will reduce the current to about three times the running current. In starting up the plant on the emergency generator it is usually better to start a portion of the smaller motors before starting the largest motor. In this way, some excitation is built up in the generator prior to applying the larger load.

The larger engines are usually slow-speed heavy engines, built for continuous duty, and they are expensive. Since the conditions for standby power would be that the engines would operate only intermittently, the high original investment would not be warranted. If several smaller generator sets are used, the electrical synchronization equipment gets rather complicated and expensive.

Horizontal centrifugal-pumping units are usually found in most distribution pump stations but vertical turbine pumps are also being used for this duty as well as for well pumps. The individual standby engine can be direct connected or belt driven.

The usual horizontal setup consists of a pump and motor on a common base plate. If there is to be a direct drive with the standby engine, in line with the pump and motor, adding a standby engine necessitates the addition of a shaft extension, flexible disengaging coupling, engine, and foundation. The unit can be driven by the engine from either the pump or motor end, whichever has the extended shaft. To get the full capacity of the pump, the engine must be capable of operating at the normal pump speed and have sufficient power to operate the pump at this speed. It is best to have an engine of sufficient power to operate the pump at any point on the pump curve, because, when an emergency arises and standby power is used, the system pressure will probably be lower than normal. The engine should be equipped with a throwout clutch and a disengaging coupling. The clutch is necessary for starting and warming up the engine and then applying the power slowly, and the disengaging coupling is necessary in order that the pump and motor may operate independently without turning the driver-half of the clutch, with consequent wear on the throwout bearings. If the pump is on the pump end, a second disengaging coupling may be used to disengage the motor when the engine is running. This is usually not necessary, but it may be desirable in some instances.

A word of caution concerning the layout of the pump and engine is in order. Present-day engines of the type normally used as standby engines rotate in a clockwise direction when viewed from the front or cranking end, and a centrifugal pump with horizontal suction and discharge must turn toward the suction. This makes it mandatory that a careful layout of the plant and piping be made in order that standard engines can be used.

A variation of this layout can be made by placing the engine alongside and parallel to the pump and motor and using a V-belt drive. This requires that an outboard bearing be

placed on the extended pump shaft and that a rolling grip clutch with pulleys be added. This type of setup requires less length of pump station and allows for flexibility of relative speed of pump and engine. The relative speed of the driving and driven machine can be changed by varying the size of pulleys. Here again, the matter of rotation must be considered. Placing the engine next to the motor reduces the accessibility of the motor unless the engine and generator are placed several feet apart. Belt guards will be necessary for safety and these will block the passage between motor and engine.

In order to supply auxiliary power to vertical units, a right-angle drive and coupling are needed. The right-angle drive can be obtained in gear ratios as needed for increasing or decreasing the relative speed of the engine and pump which gives a selection of speed for the engine, and the designer is not bound to an engine with speed as the speed of the pump, as is true with direct-connected horizontal units. Right angle–drive equipment for dual drive does not ordinarily contain vertical thrust bearings and the thrust bearing in the electric motor must be depended upon to carry all vertical thrust. The motor, therefore, cannot be disengaged and the rotor must turn with the pump, making it necessary, when driving with the engine, to engage the clutch very carefully and gradually bring the unit up to speed. Automatic or overriding clutches are available, but they are not recommended for larger units. If the unit is equipped with the automatic clutch and is brought up to speed, and if the engine misses fire for several revolutions, the pump and rotor speed will not reduce as rapidly as that of the engine. When the engine begins to fire again, it is under no load and it races until it reaches the speed of the pump and rotor and hits it with a bang; the consequence is a broken shaft or rotor spider. This can be overcome by the use of a manually engaged coupling which holds the same speeds for the pump and engine.

The damage caused by shock loads can be minimized by the use of a screwed coupling with a shear pin. In the event of a shock load, whether it be from an automatic engagement or from a too-fast operation of the engine clutch, the pin will shear, the coupling will unscrew, and the shaft will rise through the thrust bearing, causing no major damage. This shear pin arrangement can be used only with standard hollow-shaft motors with the thrust bearing in the top of the motor. It cannot be used with motors having bearings in the bottom.

Summary

There is a definite need for standby power in electric-powered plants where there is a possibility of power outage. The actual amount of standby power needed can be determined only after an intelligent and judicious study of all factors involved and a careful economic balance between storage and standby power have been made. After the necessary amount of standby power is determined, the designer has a choice between engine generator sets and individual engine drives. In the selection of the pumps to be used, the designer should take into account the space needed for vertical or horizontal pumps with the auxiliary engine, and then select the type of drive to be used.

Reference

1. *Standard Schedule for Grading Cities and Towns of the United States.* Natl. Board of Fire Underwriters, New York (1942); *Jour. AWWA,* **34**: *following* p. 1584 (Oct. 1942).

Palatability Should Not Be Seasonal

Concentrations of algae, and trade wastes in raw water supplies will vary considerably depending upon weather conditions and stream flow. Therefore, water-plant operators must keep on their toes, making frequent Threshold Odor Tests to check the required dosages of AQUA NUCHAR activated carbon necessary to reduce odor concentrations to provide a palatable water. From the standpoint of economy, these tests are a must, for they indicate when more AQUA NUCHAR is needed, or when the dosage can be cut back.

Our Research staff will gladly, without obligation, give your plant a complete odor survey and recommend how and where AQUA NUCHAR can best be used to produce palatable water.

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For more than 50 years, Neptune has built fine meters designed to earn more and cost less. Many 50-year-old Tridents are still in service . . . perhaps in your own community . . . living proof that the Tridents you buy today will be a credit to your water system for many long years to come.

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Branch Offices in Principal American and Canadian Cities.

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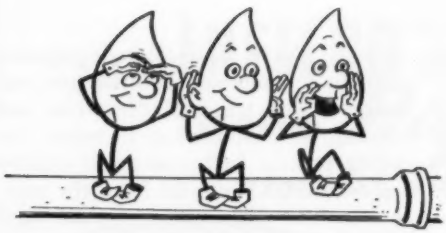

Percolation and Runoff

Water is still where you find it, but the finding is getting more and more difficult these days, and not the least reason is that so many finders are keepers. By far the keepingest, of course, are the supplemental irrigators, whose use of water is virtually 100 per cent consumptive. John R. Davis, in the text section of this issue (p. 982), gives a picture of where today's 100 bgd of kept water is being consumed and of the recent phenomenal growth of the practice of supplementation in humid areas. Dan Jones (p. 993) and Dwight Metzler (p. 999) give perspective to the picture with discussions of the calamitous effects of upstream keeping on Nebraska and Kansas community water supplies during last summer's drought—and drought time, of course, is always peak keeping time.

In discussing the adequacy of our water resources to meet the requirements of irrigation, industry, and public water supply, Davis indicates that: "Most people feel that there will be enough water for everyone, provided the job is handled in the right way." All of which would be fine if we didn't have a pretty good idea of how it will most probably be handled. Although enough rain falls on us to take care of all our needs, it unfortunately doesn't distribute itself equitably in time or space. Thus, until the mammoth physical job of making the proper distribution can be accomplished, the "handling" has to be a political parceling out of what is available when we all want it. Actually, this has been going on for decades in the West, and recently the Midwest and East have been waking up to the fact that water is precious stuff, the rights to which need to be considered and defined. At the moment 29 different states have special commissions or special legislative committees working on some form of water resources legislation:

Arkansas	Montana
California	Nebraska
Colorado	New Mexico
Connecticut	North Carolina
Delaware	North Dakota
Florida	Ohio
Georgia	Oklahoma
Indiana	Oregon
Iowa	Rhode Island
Kansas	South Carolina
Louisiana	South Dakota
Maryland	Tennessee
Massachusetts	Texas
Michigan	Washington
	Wisconsin

And with population and per capita use, as well as irrigation, skyrocketing, there should be at least 19 more states on the list before long. Meanwhile, it seems fairly obvious that it

(Continued on page 36 P&R)

(Continued from page 35 P&R)

will be in the legislatures of the land that many of our water works will have to seek their water. And politics being what they are, the finding will undoubtedly have to be spelled f-i-g-h-t-i-n-g—at least until the voters get really thirsty.

"Thump the experts" was an expression we used not so long ago to describe the trend toward disbelieving scientific authorities in favor of imaginative laymen in the dispute over fluoridation. And now, too soon, we have to trot it out again in reporting the action of the Federal Trade Commission in a preliminary decision dismissing, for lack of proof, charges that the operation and advantages of the Evis Water Conditioner had been misrepresented. Against the testimony of 100 witnesses—92 of them satisfied users of the device—the opinions of 22 scientists and other experts, "based in part on tests performed with the device," were overwhelmed. Summing up the testimony, the FTC examiner noted that the device appears to operate on a principle unknown to, or unrecognized by, present-day science. In view of this and of the fact that the scientific tests supposed to prove misrepresentation failed to comply in every detail with the manufacturer's instructions for installation and operation, the examiner said: "We must not take the risk of interfering with the development of a device which may prove to be the first practical application of a scientific principle heretofore undiscovered."

Noting that the FTC case against ADX-2 battery additive was dropped on just about the same basis at just about the same time, we feel that the coast must now be clear for the introduction of AWWA's Longevity Capsules. These blue-colored capsules contain a compound of hydrogen and oxygen, with traces of deuterium and tritium, so combined as to retard the aging process in humans *when taken as directed*. Withheld from the market until now because we did not want to reveal the secret life-prolonging interaction of the elements involved, "Longies" can now be introduced unexplained just as soon as a suitable marketing organization can be established. Advertising ought to be a snap, too, for who will be able to resist this home Fountain of Youth? Just imagine how striking an ad could be built around: "Be Late for Your Own Funeral, Take Longies!" And, of course, no one alive could ever complain that they didn't work.

Caveat emptor, here we come!

Thumping the experts is, of course, an almost ancient, if not exactly venerable, practice in the field of water supply, where undiscovered principles have been applied the world over for hundreds of years under the name of dowsing. Examined by the rules of evidence established in the FTC hearings, dowsing would undoubtedly come away not only cleared, but congratulated for open-mindedness. All of which has had us so busy reading *Recanting Made Easy* and *How to Kowtow to Dowsers* that we haven't looked to see what our diviner friends have been doing for the past 19 months —and doing they have been, as well as having been done to in the interim:

- First "do" was that of Stephan Riess of Simi Valley, Calif., who, though he is not a dowser proper, is apparently just as unprincipled scientifically in his methods of locating underground water. Although he refuses

(Continued on page 38 P&R)

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The ACCELAPAK® treating plant: A *complete single installation* water clarifying and/or softening plant. Includes "ACCELATOR" unit, slurry feeder, NEUSOL® feeder, rate of flow controller, gravity or pressure filters.

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The C.-A.-P. SYSTEM® instruments afford maximum efficiency in pneumatic control of treatment plant operation, provide sensitive flow control, accurate measurement of loss of head and rates of flow.

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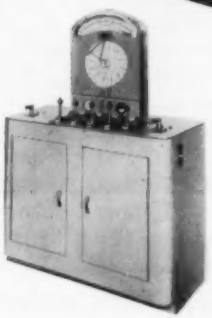

(Continued from page 36 P&R)

for now to disclose his "science," its results have been publicized far and wide by no less popular a weekly than *Collier's*. Riess's accomplishment has been the finding of water in rocky areas where geologists have felt it not worth while to explore. Riess's claim is that he has discovered the process by which "primary water"—that is, water created deep within the earth by the combination of gases—is formed, and, understanding that process, he is able, by an analysis of surface rocks, to determine where conditions are favorable for underground primary water production. Inasmuch as the rock analysis on one of his jobs cost $670 and the subsequent drilling through 300 ft of rock an additional $3,800, not too many people are likely to sample Riess's rock juice—and to those who can afford it and are lucky enough to get an adequate supply, it matters not at all whether the supply is primary, secondary, or, for that matter, septuagenary. Local geologists, however, though they admire Riess's successes, wonder about his failures and ridicule his primariness, explaining his finds as runoff into fractures in the rock structure rather than liquid reaped from the action of a "mono-atomic" water cycle of gas to liquid to crystal.

• "Do" 2 was the undoing of two dowsers in the pages of the *Water Well Journal*. First, in the March–April 1955 issue, the team of novelist Kenneth Roberts and his dowser protege Henry Gross, not to mention a local wand wielder, was given its lumps by C. R. Roseberry, a columnist for the Albany, N.Y., *Times-Union*, who described how, in one of the "successes" that went into Henry's 100 per cent record, his rod had picked one dry hole and one all but dry one, as well as completely missing a most satisfactory supply which underlay the entire property that he had dowsed, first by map from Kennebunkport, Me., and then on the scene. Then in the May–June 1955 issue, Stephan Riess's primary water was labeled "best-selling fiction" by geologist John F. Mann Jr. of the University of Southern California in an article which pointed out that, although there is such a thing as "primary" or "juvenile" water in volcanic or formerly volcanic areas, it occurs in quantities insignificant for water supplies and is so highly mineralized as to be useless for domestic, industrial, or irrigation use. Giving a list of fourteen "successes" by one of the prime primarians, Mann compares the claims with data provided by the California Div. of Water Resources and finds that none of them measures up and that at least five were complete failures.

• Third was a visit to Kenneth Roberts after his return to the ranks of novelists with the publication of *Boon Island*, a completely dowserless tale. Lewis Nichols of the *New York Times Book Review*, who made the pilgrimage to Kennebunkport, found dowsing's angry man not the least bit disengrossed with the subject of his two previous books. In fact, business is apparently going along better than ever, with Henry's wetting his twig in oil as well, and claiming a wildcatting record of 95 per cent.

• Fourth was a new wrinkle in depth determination by dowser George R. Stokes of Old Providence, Tex., whose responsibility it is to locate water and dig a well each time a buck takes a squaw on the Alabama-Coushatta Indian Reservation nearby. Wielding his forked stick for The

(Continued on page 40 P&R)

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Iron pipe, capper, lead flange and wiped joint inlets and outlets may be used in various combinations to meet your specific requirements. Stops are also available in Minneapolis pattern.

Ask your Mueller Representative, or write direct, for more information on the inverted key and other Mueller Curb Stops.

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MAIN OFFICE & FACTORY DECATUR, ILLINOIS

(Continued from page 38 P&R)

Great State, which provides each new Indian couple with a well as well as a house, Stokes turns to a straight limb for depth analysis. Suspending it over the proposed site he counts the feet of depth by the number of times the stick dips and, doing the digging himself, he, of course, never misses.

• Fifth was the early antidowsical start achieved by the *Water Well Log*, brand new publication of the Texas Water Well Drilling Contractors Assn., with the appearance in Vol. 1, No. 2, of an article on "Ground Water Investigations," by consulting hydrologist William F. Guyton of Austin, in which it was pointed out that a variety of data are required in ground water investigations but that nothing so various as a "witch stick" would be of any help.

• Sixth was the announcement in an issue of *Water Views*, publication of the Michigan Geological Survey Div., of a new dowsing technique involving the use of hungry lizards instead of forked sticks. Employing a special breed of Wisconsin springhouse lizards that get all their food out of water, one Harry S. Wett of White Rock, Md., to whom the discovery is credited, is reported to have found that by starving his lizards he could increase their sensitivity to a point where they could hear water running 200 ft underground. Then, merely by marking the point at which the hungry lizard looks intersect, the alleged Mr. Wett claims to have a foolproof divination.

• Seventh was similarly seventh sensible—the story of a swimming pool that a newly organized 350-family swimming society built high and dry

(Continued on page 42 P&R)

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Sodium Fluoride—98%

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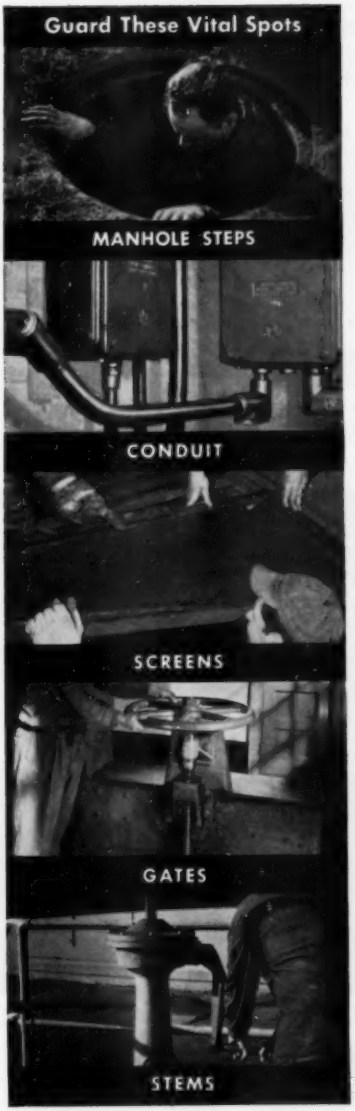

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EVERDUR IS READILY FABRICATED. Everdur alloys are available for hot or cold working, welding, free-machining, forging and casting–and can be supplied in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage and Waterworks Equipment"—or for assistance of the Technical Department in selecting the correct material for your equipment. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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COPPER-SILICON ALLOYS

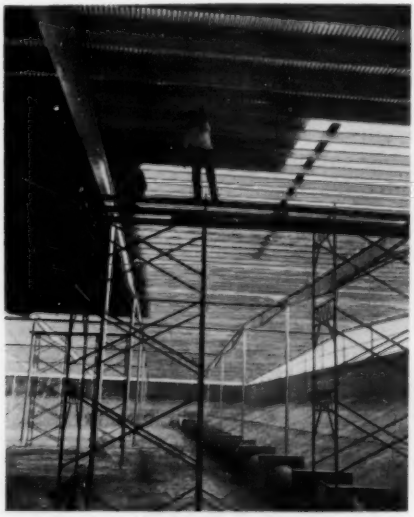
STRONG • WELDABLE • WORKABLE • CORROSION-RESISTANT

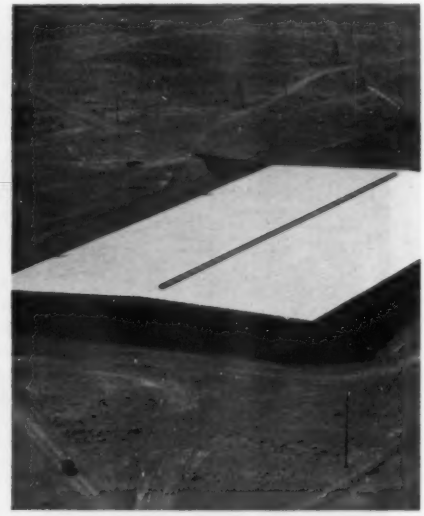
(Continued from page 40 P&R)

at Lititz, Pa., at a point selected by dowser David N. King. Rather unusual was the society's willingness to proceed with the pool before the well had been dug, merely on the chance that King would divine right, but then, living in the mousetrap capital of the world, Lititzians are accustomed to expecting the world at their door . . . and finding it there.

Despite the apparent juiciness of Riess's rocks, despite Stokes' law of water depth, despite the wizard lizards, despite even King of the dowsers, we have the distinct impression that dowsing has been more done to than doing these 19 months. That could be the result of our own lack of principle, or perhaps it's because the experts have been so much more thoroughly thumped in the past. But, regardless, rhabdomancy rolls on—and, looking at the linage, a good thing, too—for us, that is.

Harvey O. Banks has been named director of California's Dept. of Water Resources, which came into existence last month. Banks, who had been state engineer and chief of the State Div. of Water Resources, will be assisted by M. J. Shelton as deputy director of the new department. Mr. Shelton, general manager and chief engineer of Helix Irrigation Dist., in the San Diego area, is vice-chairman of AWWA's California Section.

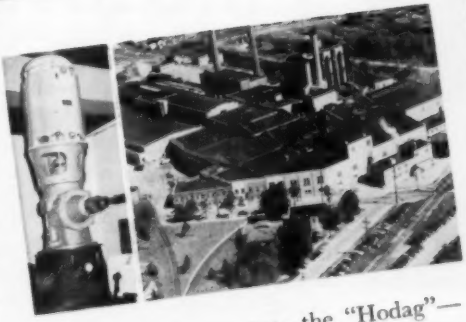


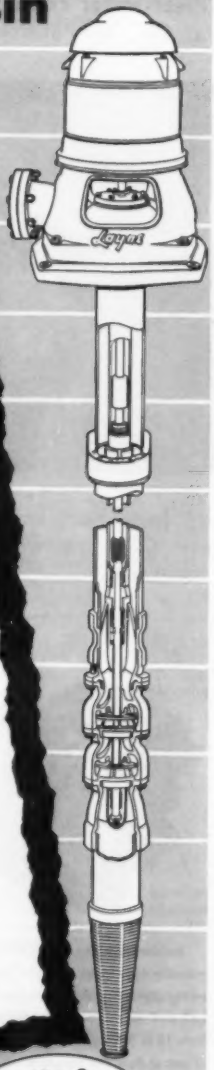


Aluminum sheeting—5¼ acres of it—was used to cover the new 30-mil gal earth embankment Charleston Heights Reservoir of the Las Vegas (Nev.) Water Dist. Photo at left shows corrugated roofing sheets (supplied by Kaiser Aluminum & Chemical Corp.) being secured to steel I-beam purlins with straw nails. At right is an aerial view of the completed cover.

(Continued on page 44 P&R)

Rhinelander, Wisconsin
. . . Relies on Layne!





An imaginary monster—the "Hodag"—first brought fame to Rhinelander, Wisconsin, and this charming smaller city is known as "the Home of the Hodag."

Smaller municipalities, as well as the great metropolitan centers of the nation, know that utmost dependability in pumps is spelled L-A-Y-N-E.

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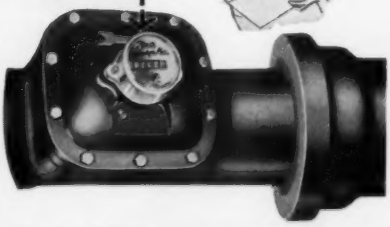
(Continued from page 42 P&R)

Guest water commissioner of Atlanta, Ga., last March 30 was none other than Throckmorton P. Gildersleeve, the water works field's representative extraordinary in the mythical metropolis of Summerfield. Guest TV star at the same time was none other than AWWA prexy Paul Weir, who appeared with Gildy on the WSB–TV show, "Today in Georgia," and there presented The Great G not only with a commission duly signed by Atlanta's mayor, but with a Willing Water lapel pin (see cut). In getting Willing Water into the act, Paul really focused attention on the nominal resemblance between these two water works characters, for, actually, Gildy is practically Willie's namesake, his offstage name being Willard Waterman. Which, of course, gives us the opportunity to caption the cut: "Willard Waterman's Water Works Well-Wishers Were Weir With Willing Water." Well, we won't!

(Continued on page 46 P&R)

don't surmise...

totalize!



Builders-Providence PROPELOFLO® is a direct-reading, propeller-type meter designed for main line totalizing of water consumption . . . available in 2 to 20 inch sizes . . . with flanged, bell and spigot, and threaded ends. Rated capacities range from 15 to 5800 gpm . . . accurate to within plus or minus 2% of actual flow. For complete information, write to **BUILDERS-PROVIDENCE, INC.,** 365 Harris Ave., Providence 1, R. I. . . . division of

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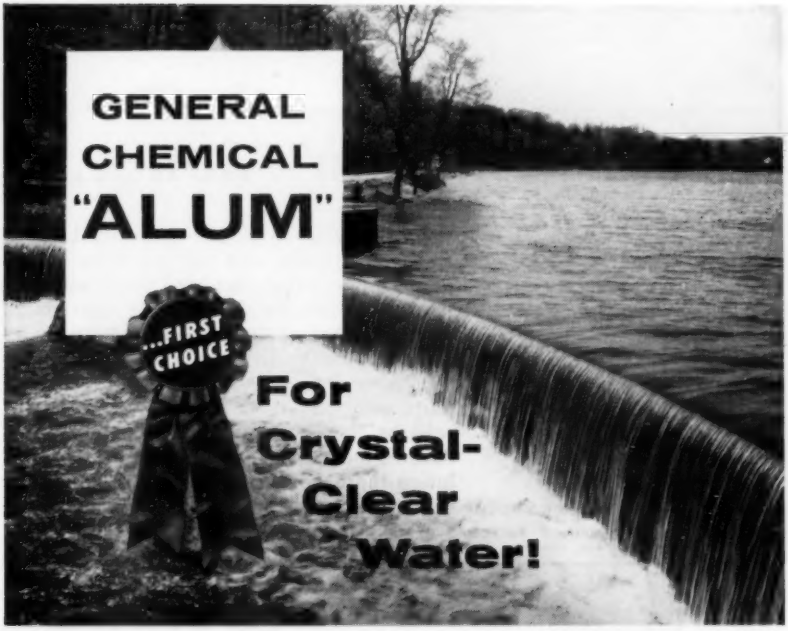

Here's the alum of unvarying quality and uniformity . . . a highly efficient, dependable and economical coagulant for removing turbidity from water, for reducing tastes, odors, colors. Water men, America over, prefer General Chemical Aluminum Sulfate for making water good to drink and crystal clear. Make it your choice, too!

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- Has no chlorine demand
- Aids in reduction of tastes and odors
- Is a low cost coagulant
- Superior in tests against other coagulants
- High in quality. Its constant uniformity can be depended upon

For Sewage Treatment

- Clean, easy to handle
- Dry feeds well or dissolves readily for solution feeding; liquid alum also available in many areas
- Simple application. Requires only low-cost feeding apparatus and minimum attention
- Clear, colorless effluents are possible
- Sludge digests readily
- Treated digested sludge dries quickly with minimum of odor
- Chlorine consumption is cut, due to lower demand of clarified sewage
- Economical to use

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Fordin' Along...

About 1600, when all the water for London's inhabitants was carried from the Thames, its tributaries and from wells, there were about 4000 water carriers who organized their own Guild and were powerful enough to keep private citizens away from the water sources. Later conduits were laid to bring water from the suburbs to public cisterns and as these became inadequate for the growing population there were violent struggles among the water carriers, so that it became necessary to issue special orders to prohibit the use of weapons in securing a place in the lines.

(Continued from page 44 P&R)

Engineers Joint Council is currently mailing out questionnaires to representative segments of industrial and governmental organizations employing engineering graduates, for its second triennial survey of the earnings of engineering graduates throughout the country. In September questionnaires will be sent to faculty members of engineering colleges through their respective deans of engineering. The replies to the basic questionnaires to industry and government, which will be prepared by key personnel or administrative managers of the organizations, together with the replies from engineering educators, will serve as the basis for the publication "Professional Income of Engineers—1956." The survey, which will analyze the current structure of salaries of engineering graduates employed in the United States, will be of unquestionable value to those interested in engineering employment conditions. Prompt completion and return of questionnaires by the organizations receiving them will be of great help in this project.

R. F. Hendren, manager of plants, Chicago Bridge & Iron Co., has been elected a vice-president of the firm. He joined the company in 1923 and was made manager of plants in 1947.

Alfred C. Leonard has been appointed an associate in the consulting firm of Malcolm Pirnie Engrs., New York. Mr. Leonard has been with the organization since 1949.

(Continued on page 48 P&R)

The
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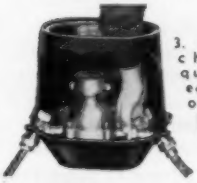
Yokebox

1. Small lid, clean meter, speeds meter reading.

2. Easy to handle, quickly installed as a unit.



3. Meter changes quick and easy, without cumbersome tools.

4. Service valve easily operated and well protected.

A Better Meter Setting for Shallow Services

A simple, compact meter housing, complete with service valve, for warm climate installations. The modern and better way to install water meters. Gives better protection, keeps meter cleaner. An investment in easier meter reading, longer meter life and greater revenue.

Write for information on the Yokebox.

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FOR BETTER WATER SERVICES

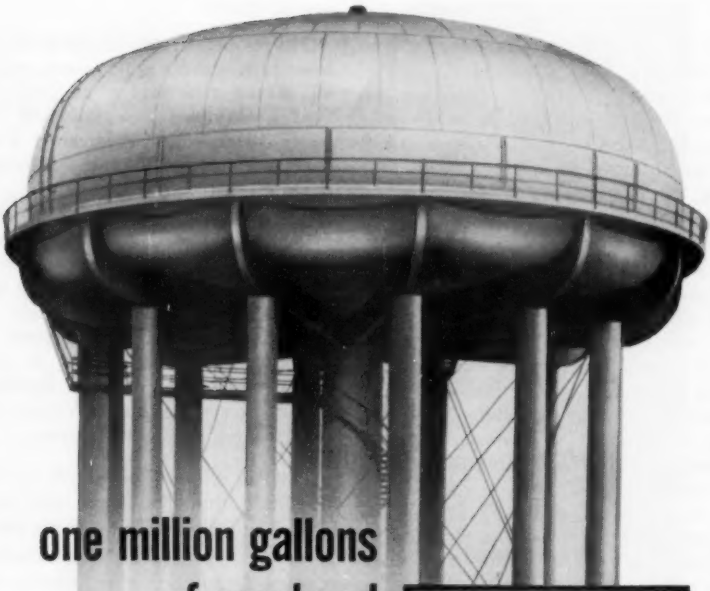
THE FORD METER BOX COMPANY, INC. Wabash, Indiana

(*Continued from page 46 P&R*)

The rat-race aspect of life these days has had many manifestations in many fields of activity. In the water works field, it has been most noticeable, perhaps, in attempts to keep up with the demands of a burgeoning and thirstening population, but even in ordinary day-to-day operations, the pressure seems to be on. In meter reading, for instance, there has been clear indication of rat-racism in the trend toward the use of outside meter settings, in such speedup devices as the gas-powered three-wheelers provided to meter readers in Atlanta, and even in the current concern with dog-bite-proofing metermen. Perhaps the most eloquent acknowledgment of the current urge to ulcers was made by a judge in the common pleas court of Montgomery County, Ohio, when he rendered a decision concerning the reasonableness of a resolution requiring outside water meter settings in certain new homes in the county. Indicating by the style and quantity of his language that he, himself, was no rat racer, Judge Thomas said:

> The evidence in this matter discloses that both public and private utility operations are attempting to get in step in the ranks of the march of time in reference to the utilization of time-saving methods and services.
>
> Prior to the advent of home time-saving devices, electric, gas, and water meters were placed in all types of homes. During this early period, the occupant of the home had time to admit the meter reader and pass the time of day with him; also had time to bake bread, can fruit, vegetables, picallili, chowchow, and preserves; time to lay in sufficient quantities of foodstuffs for use during the winter; time to make clothes; time to wash on the Armstrong rubadub board; time to attend Chautauqua lectures, attend church and all of its activities, including time to read the Bible and prepare the Sunday school lesson and time to see the preacher; time to attend Larkin Soap Clubs; time to save Lionhead and Arbuckle wrappers for the purpose of obtaining bric-a-brac for home beautification; time to wash windows; time to sit up with the sick, prepare food for the deceased neighbor's household, and attend wakes and funerals; time to visit old and new neighbors; time to view nickelodeons and see the stage versions of *East Lynne, Ten Nights in a Bar Room*, and the *Last Days of Pompeii;* time to look for the mailman; time to play parcheesi, old maid, post office, "button, button, who's got the button?," dominoes, and pitch horseshoes; time to practice on the piano, mandolin, saxophone, drums, and violin; time to plant and tend the garden; time to talk to and feed the parrot; time to see all parades; time to cut the children's hair; time in the mornings to build fires in the cook stove and base burner and time to keep them burning; time for a little gossip to go in one ear and out over the back fence to Mrs. Murphy; and time to take a snooze in the hammock stretched between the old apple trees.
>
> After supper (not dinner) in the evenings, time to look at the stereopticon slides; time to listen to the roar of the ocean by placing the ear to conch shells; time to read Graustark, Huck Finn, and Tom Sawyer; time to play the organ and sing hymns; time to pop corn and make popcorn balls, time for taffy pulls; time to mend clothes, darn socks, and do plenty of knitting, quilting, and crocheting; time to tell bedtime stories to the children; and plenty of time left to get to bed before twelve o'clock.
>
> Upon the advent of our modern time-saving devices, such as electric washing machines, sewing machines, clothes driers, hair driers, permanent waving machines, blowers, lawnmowers, sweepers, refrigerators, televisions, radios, record players, dishwashers, disposals, roasters, toasters, mixers, stoves, air-conditioning units, razors, clippers, scooters, automobiles, tele-

(*Continued on page 50 P&R*)



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(Continued from page 48 P&R)

phones, motorcycles, charge accounts, layaway accounts, supermarkets, and all types of easy-payment plans, it seems we do not have quite enough time to go around.

This significant fact was forcibly called to the attention of the Court during this hearing. It appears from the evidence that many wives are now working, probably for the purpose of implementing the family's income in order to purchase the latest, last-word, up-to-the-minute time-saving gadgets for the home, and under these conditions the key to the home is either left with the utility company or there is no one home to admit meter readers during the daytime, and where the wife is at home she is so busily engaged in operating these time-saving devices, or supervising the repair of one or more of them, that it is inconvenient for her to take time out from what she is doing to open and close the door for the meter reader.

The evidence further discloses that in some homes there is not space enough for all of the time-saving gadgets and the meters. Where this situation obtains, meter readers are confronted with difficulties comparable to those facing participants in treasure hunts.

The evidence further disclosed that present-day meter readers do not have sufficient time for the work allocated to them to go in and out of homes in order successfully to complete their quotas. Therefore, the evidence suggests that in the interest of time-saving, it would be better for all meters to be installed outside of homes for the convenience of both homeowners and meter readers.

All of which has given us time to conclude that the race with the rats could be won easily by some electronic hookup that would permit reading the meters from the water works office.

(Continued on page 52 P&R)

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(Continued from page 50 P&R)

Doubling in brass is what the Canadian Section brass is busy doing these days. Section Chairman V. A. McKillop, general manager of the Public Utilities Commission at London, Ont., has taken over the presidency of the Engineering Institute of Canada for the ensuing year, which places him in the unique position of leader of both engineering and water supply activities in the Dominion. And Section Secretary A. E. Berry, director of the San. Eng. Div. of the Ontario Dept. of Health, has been appointed general manager and chief engineer of the recently established Ontario Water Resources Commission. With the completion of its membership roster, the commission has begun to take up its functions in the fields of water and sewerage.

V. A. McKillop

A. E. Berry

A. F. Porzelius has retired as manager of the Chattanooga, Tenn., Water Co. His successor will be Edward S. Tillotson, who has been associated with American Water Works Co. for many years. Mr. Porzelius will engage in consulting work.

(Continued on page 54 P&R)

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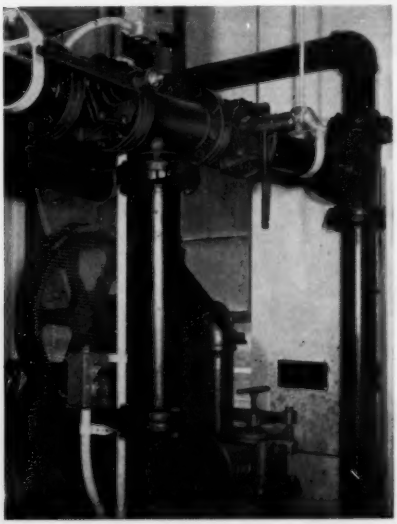
(Continued from page 52 P&R)

Safe water quality may not be enough any longer to protect a water utility against suit—at least in Ohio, safe quantity, too, may be required if the ruling of a judge in the common pleas court in Cleveland is taken as precedent. That ruling permitted a woman pedestrian who had been struck by a car to sue not only the driver and passenger in the car but the race track miles away in whose tavern they had been served "staggering amounts of intoxicating beverages" before they had headed homeward. Following that ruling to its illogical conclusion we would certainly expect that a water utility could be sued for a bathtub drowning, as well as for a thousand other lesser calamities that too much water could undoubtedly cause around the home or store or plant. And were we Ohioan, we'd certainly think twice before serving cocktails to our friends. There ought to be a law!

Fighting flood with flood was the technique which the Pacific Power & Light Co. at Portland, Ore., used last spring to reduce the damage caused by inundation of the basement of its main warehouse by waters of the Willamette River. Remembering the cleanup problem of past floods, when silt and slime covered everything in the basement, company executives decided to flood the area in advance with clean water from the public system. By thus equalizing the hydrostatic pressure they not only kept the silt from being carried in by the flood waters, but added another to the almost endless list of water's powers. It's an ill rain. . . .

(Continued on page 80 P&R)



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TREATMENT—GENERAL

Conditions in Activated Sludge Process During Frothing. G. P. EDWARDS & M. E. GINN. Ind. Eng. Chem., **48**:246 ('56). During aeration cycle in activated sludge plant treating detergent-contg. waste, much of detergent is rapidly adsorbed by sludge. At same time, surface tension of supernatant liquid increases as does oxidation-reduction potential of mixed liquid. Frothing seems independent of these factors.—*CA*

Instrumentation of a Water Treatment Plant. G. E. REID. Instruments & Automation, **28**:1742 ('55). Water-treatment plant, newly constructed to provide filtered zeolite-softened water for use in sewage steam-generation plants of steel company, is described. Raw water is variable Monongahela R. water. pH adjustment, sand filtration, and zeolite softening constitute major unit of plant. Instrumentation, described at some length, was developed to provide const. and continuous flow of water with extremely low hardness and almost no suspended solids. Most control devices are compressed air–activated units rather than conventional water pressure–operated controllers.—*CA*

Removal of Inorganic Arsenic From Drinking Water Under Field Conditions. R. I. BEREZMAN. Gigiena i Sanit. 1955 (U.S.S.R.), **12**:40. Treatment of waters with 10% aq. $FeCl_3$ and MgO with filtration gave residue of 0.1–1.1 mg/l of As_2O_3 with satisfactory clarity and taste; method, however, is not desirable since it enriches fluid with Cl and Mg ions. Ppt. of $Fe(OH)_3$ added in suspension to test waters gave residual As_2O_3 of about 0.6 mg/l; slight ironlike taste is imparted to waters while Cl concn. and pH remain almost unchanged.—*CA*

Water Purification With Activated Carbons. W. A. HELBIG. Plating, **42**:1044 ('55). Use is recommended for removing organics from rinse waters prior to further ion-exchange treatment; this protects resins from contamination.—*CA*

Detergents in Water Supplies. J. C. VAUGHN & R. F. FALKENTHAL. Ind. Eng. Chem., **48**:241 ('56). Problems assocd. with detergents in water supplies are: foam on settling basins, taste and odor, coagulation and sedimentation, Fe, foaming of finished waters, and quality deterioration in distribution system. Removal of detergents by adsorbents follows Freundlich isotherm. Most effective adsorbent was found to be sediment from settling basins.—*CA*

Some Economic Data on Chemical Treatment of Gulf Coast Cooling Waters. J. M. BROOKS. Corrosion, **11**:61 ('55). Based on reported expenditures for inhibitors used in cooling towers of 16 Gulf Coast refineries and chem. plants, it is estd. that national cost of inhibitors in chem. and refining industry is approx. $22,500,000. Inhibitors are used in cooling water to regulate pH, reduce scale and corrosion, and control algae. Materials used include H_2SO_4, NaOH, S, glucosates, Na polyphosphate, $Na_2Cr_2O_7$, Cl, and com. products. Avg. cost of treating recirculating water on Gulf Coast is estd. to be $2.21 per billion Btu.—*CA*

The Magnesia Method of Desilicizing Water. B. D. BRVANSKII & V. I. ATROSHCHENKO. Khim. Prom. (U.S.S.R.), p. 478 ('55). MgO method of SiO_2 elimination is at present most effective. Dolomites are best raw materials for use in process and valuable properties for that treatment are developed by ignition of dolomite. SiO_2 removal from water by MgO from dolomite is more effective as MgO content in dolomite increases. Treatment temp. is very important in effectiveness of treatment. River water was successfully treated in 25 min at 95°, while 24 hrs were required at 40°; an

(Continued on page 64 P&R)

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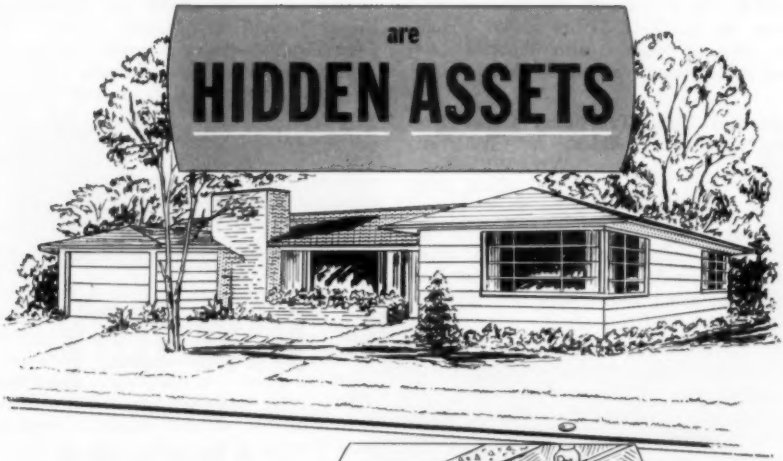

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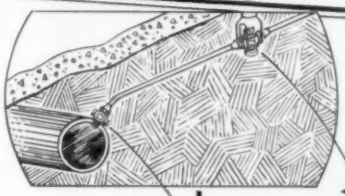

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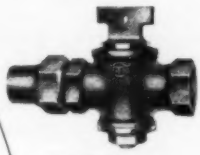

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(Continued from page 62 P&R)

artesian well water required 80-min contact for 97.4% SiO_2 removal, and lowered SiO_2 content by 93.2% in 24 hrs at 40°. Dolomite calcining temp. is also important, and drops with higher calcination temp.—*CA*

Alum and Lime Treatment Cures Iron and Turbidity Troubles. W. W. Armstrong & H. E. Case. Wtr. Wks. Eng., **108**:856 ('55). 1 steel plant solved problem of incrustation in water distr. system attributed to high turbidity and iron in raw water. New clarification unit and chem. feeder were installed. Alum was used as coagulating agent and lime to raise pH and reduce iron.—*PHEA*

Chlorinated Tank Water on Ships. Z. Buczowska & J. Dabrowska. Roczniki Panstwowego Zakladu Hig. (Pol.), **6**:261 ('55). Comparison has been made between different methods of chlorination for disinfection and preservation of drinking water on ships. Methods were: (a) chlorination with smallest possible dose of free Cl; (b) chloramination following NH_3 treatment; and (c) chlorination followed by removal of excess Cl with activated charcoal. Of 1st two methods chloramination appears to be most effective. Because of use of small doses of Cl neither of these methods imparts any objectionable taste or odor. Last technique is most effective one; however, it cannot be used on ships because of difficulties encountered in process control and in removal of excess Cl. Microorganisms used for evaluation of methods were *Escherichia coli* and *Bacillus subtilis*.—*CA*

Water—How It's Treated. E. Nordell. Chem. Eng., **62**:175 ('55). Process data, including costs, are presented for various types of water-conditioning processes to aid in choosing best process for any given case. Processes included are (1) Na cation exchange, (2) H cation exchange, (3) ion-exchange demineralization with both cation and anion exchangers, (4) cold lime soda, (5) hot lime soda, (6) coagulation, settling, and filtration, (7) aeration, (8) deaeration, and (9) Fe and Mn removal.—*CA*

Recent Developments in the Water Supply to the City of Dublin. G. A. Cremins. Trans. Instn. Civ. Engrs. Ire., **80**:55 ('54). Water supply for Dublin was formerly obtained from river Poddle, canals, and 2 reservoirs. To meet increasing demand for water, impounding reservoir was constructed on river Liffey. Water, derived from peat moors, is soft, slightly alkaline, and colored and has pH value of 7.1–7.5. Treatment consists of coagulation with aluminium sulfate and whiting, sedimentation and passage through rapid sand filters. pH value is finally adjusted to 8.3 by addition of lime, and water is chlorinated to give residual concn. of free chlorine of 0.2 ppm. The plant is being constructed in 4 stages, each part having capacity of 5 mgd, to give a total capac. of 20 mgd. 2 units in operation. Details of construction and operation of plant are given. At Ballyboden water works, where water from Bohernabreena catchment area is treated, water is passed through slow sand filters and disinfected with chlorine and ammonia. Water is, however, highly colored and is planned to construct plant with capac. of 4 mgd to treat water by coagulation and on rapid sand filters. Filter wash water will be recirculated through plant and sludge will be discharged to municipal sewers during night.—*WPA*

WELLS AND GROUND WATER

Geology and Economic Resources of the Ohio River Valley in West Virginia. III. Ground-Water Resources of the Ohio River Valley in West Virginia. C. W. Carlston & G. D. Graeff Jr. West Va. Geol. Survey **22**, Pt. 3:1 ('55). Chem. analyses are given of 105 samples of ground water, mainly moderately hard to hard bicarbonate waters, and of 25 samples from Ohio River.—*CA*

The Ground-Water Resources of Greene County, New York. J. M. Berdan. N.Y. Dept. Conservation, Water Power and Control Comm., Bull. **GW-34**:1 ('54). Chem. anals. are given of 48 samples. Water from Deepskill and Normanskill shales and from limestone formations was hard to moderately hard.—*CA*

Ground-Water Data for Dwyer Quadrangle, Grant and Luna Counties, New Mexico. F. X. Bushman. New Mexico,

(Continued on page 66 P&R)

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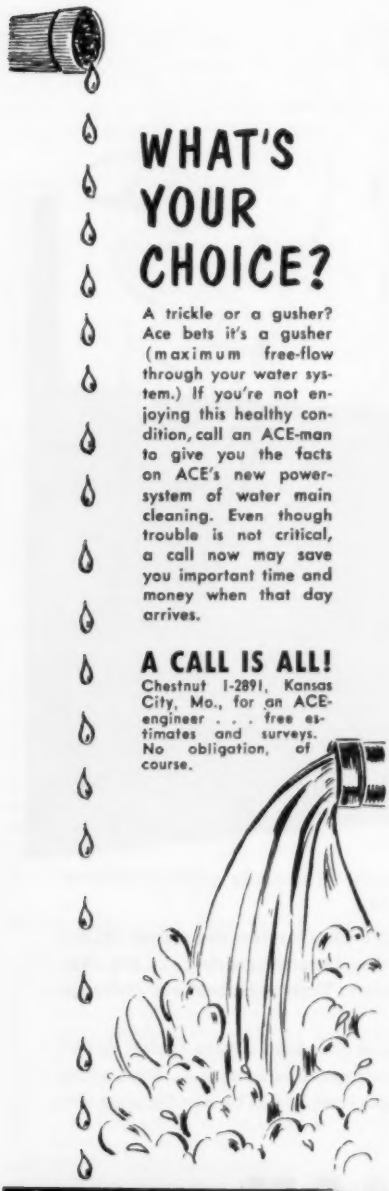
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(*Continued from page 64 P&R*)

Bur. Mines and Mineral Resources, Circ. No. **37**:1 ('55). Chem. anals. are given of 30 samples including 4 from hot springs. Most waters are high in bicarbonate content. Hot springs contained 5–16 ppm F.—*CA*

Metamorphism of Natural Waters in the Crust of Weathering. I. I. I. CHEBOTAREV. Geochim. et Cosmochim. Acta, **8**: 22 ('55). Broad problems of origin, occurrence, and distr. of sol. salts in natural waters and brines of weathered zone of earth's crust are discussed. Relations between transport and flow of waters to their mineral content are described with reference to anal. of weathering process. Theoretical and exptl. chem. and geochem. evidence are cited to show leaching and cementing effects of water on various types of rocks. Depending on nature of aquifer and phase of weathering, mineral waters may contain predominantly bicarbonates, sulfates, or chlorides of Na and K.—*CA*

Character of Minnesota Well Waters, With Special Emphasis on the St. Cloud Region and Stearns County. M. A. KIESS. Proc. Minn. Acad. Sci., **20**:23 ('52). Anals. for Fe, Mn, Ca, Mg, CO_3^{--}, SO_4^{--}, and Cl^- are given. St. Cloud wells run lower in salinity than those of state and county, but still higher than Mississippi River.—*CA*

Hydrochemical Properties of Underground Waters Associated With Underground and Overground Peat Deposits. P. V. ASTAPENYA & T. A. KAGAN. Vestsi Akad. Navuk Belarus. S.S.R. (Russ.), No. 1: 177 ('54). 6 different samples of peats and humus-contg. rocks, some of them taken as deep as 100 m underground, were mixed 1:100 with several samples of waters contg. SO_4^{--} and NO_3^- and then kept under anaerobic conditions in dark at 10–12° for 3–8 months. In all water samples investigated, amts. of SO_4^{--} and NO_3^- ions greatly decreased; H_2S, not present in fresh waters, was found in varying amts. in all samples at end of expt. This indicates presence of desulfatizing and denitrifying bacteria in peats and humus-contg. rocks. It further explains absence of SO_4^{--} and NO_3^- and NO_2^- in underground waters taken in several places in Byelorussia at depths of 100 m and more. Desulfatizing coeff., $(SO_4^{--})/(SO_4^{--} + Cl^-)$,

(*Continued on page 68 P&R*)

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(Continued from page 66 P&R)

of underground waters which are assocd. with org. residues is (in av. of 49 different springs) 0.33, as compared with 0.57 for waters not in touch with org. residues. Thus, coeff. larger than 0.5 can be used to differentiate underground waters not assocd. from those assocd. with peat deposits or other org. residues in soil.—*CA*

Geology and Ground-Water Resources of the Alexandria Area, Rapides Parish, Louisiana. M. L. KLUG. Geol. Survey Water Resources Pamphlet No. 3:1 ('55). Chem. anals. of 6 waters are given; they had high $NaHCO_3$ content.—*CA*

The Hydrochemical Regime of the Steppe Ponds in the Forest Steppe Zone During High Waters. P. P. VORONKOV. Gidrokhim. Materialy (Russ.), 22:45 ('54). Under conditions of heavy rainfall, waters of ponds even in most arid regions are low in minerals (200–300 mg/l) and have favorable bicarbonate content, with Ca prevailing. During dry periods, when water level drops, mineral content rises to 4,000–6,000 mg/l and even higher. Compn. of waters in ponds is detd. by compn. of soil moisture and of ground waters which in measure det. compn. of former. For examn. of dynamics of mineral content of waters in ponds, anals. were made of runoff waters entering them after heavy rains. From chernozem soils low in org. matter, surface waters of rain on Sep. 13 contained around 110 mg/l salts contg. high HCO_3 and Ca content. Thawing water supplied appreciable quantities of SO_4, and total minerals varied from 166 to 416 mg/l in 2 sep. samplings. As surface waters cease their movement, ground waters and excess soil moisture begin to move and these contain more minerals. Data are presented on HCO_3, SO_4, Cl, Ca, Mg, and K + Na contents of surface runoff waters, river waters, and pond waters during spring in southern part of Don R. basin. Similar data and discussions are presented for forest steppe zone in northern part of Don R. basin.—*CA*

(Continued on page 70 P&R)

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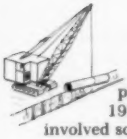

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(*Continued from page 68 P&R*)

DISTRIBUTION SYSTEMS

The Lining With Rubber of a Large Service Reservoir Damaged by Mining Subsidence. A. G. McLellan. Wat. Sanit. Engr., 5:206 ('55). Mill Hill Reservoir, constructed by Sunderland and South Shields Water Company, is placed over and along whinstone barrier between two coalfields. Areas of complete extraction surround reservoir, giving ideal conditions for differential settlement. Leakages soon occurred through wall contraction joints, and escaping water scoured at foundations. In 1949, all cavities found were filled with concrete (location of cavities is shown in diagram). Grouting was only serviceable as immediate measure. Narrow concrete panel coated with bitumen was successful where placed, but problem remained of anticipating movements and fractures. Fig. 3 shows treatment of cracks by laying rubber strips, but operation was difficult to perform. It was decided that complete covering of water surface with impervious membrane was only solution. Plastics were impermeable, but there was no satisfactory method of joining sheets. The cost of rubber was excessive, but when compared with probable cost of having to replace reservoir it appeared to be practicable. Rubber bag which would rest freely on floor and be pegged to wall was proposed. Pilot experiments were carried out on a complicated site which included wall junction, 24-in. diam. pipe, curved surface between wall and floor, and column base. By having extra layer of rubber to reinforce mitres at wall junctions, mixing tank was rendered completely water-tight. Diagrams show method of securing rubber lining to walls. Life of lining is given as at least 20 years. Dunlop Rubber Co. Ltd. were able to produce material which combined low permanent set, high extensibility, and suitability for storing potable water.—*PHEA*

Plastic Tubes for Water Mains. B. Nietsch. Gas, Wasser, Warme (Ger.), 8:179 ('54). Author reports on nature and development of plastics in general.

(*Continued on page 72 P&R*)

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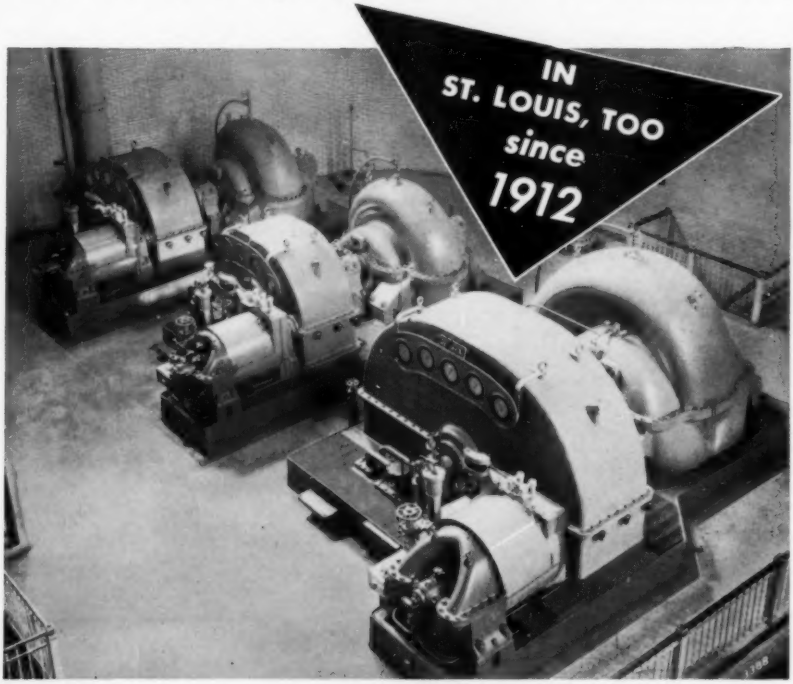

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Waste-Water Detection and Remote-Control Indication by Means of Meters. A. GILBERT. Munic. Utilities (Can.), **92**:36 ('54). Kent gate-type meter, used in Gt. Brit. for checking waste and misuse of water, described briefly. Body of meter, of c.i., jointed into main, contains weighted gun-metal gate suspended on stainless steel knife-edge. Rate of flow determines opening of gate and latter is recorded on chart mounted on drum rotated by clock mechanism at desired 1 of 3 speeds, once in 6 hr, 24 hr, or 7 days. Accuracy 2% at max. flow to 10% at 1/40 flow. Meter bodies can be fixed in mains at various locations and upper recording portion transferred from 1 location to another. By use of such meters, flow tests can be made for whole area controlled by meter or for sections regulated by valves at strategic points which help to pin-point highest flows to particular sections. Remote recording app. for meters and telephonic level indicators and transmitters also outlined.—*R. E. Thompson*

HYDRAULICS

Lubricated Plug Valves Gain Wider Use in Water Works. T. H. M. TAYLOR. Wtr. & Sew. Wks., **102**:514 ('55). Due to design features, lubricated plug valves from ½" to

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(Continued from page 72 P&R)

30" are gaining wider application in water works field. Improved features include quick opening and closing by quarter-turn, simple and compact design of body, ground-joint types of shoulder instead of stuffiing box, and pressure lubrication of plug. Advantages of lubricated plug valves are: flow can be reversed without danger of leakage or jamming, elimination of abrasion caused by dirt and debris, and no galling or "freezing" due to long periods of inactivity. Servicing suggestions include snug adjustment of plug, full lubricant system, turning of plug while lubricating.—*PHEA*

Compressed Air in Water Works. E. C. Powers. Wtr. & Sew. Wks., 102:480 ('55). Use of compressed air in water works as source of power has been very limited, despite fact that it has had very many good applications. Air lift pumping gets away from submerged parts and worries of crooked well shafts. Installation costs are lower, accessibility and maint. are simplified, and contamn. reduced. Compressed air has great promise in aeration. Advantages of aeration by compressed air include: [1] since air can be made to pass through smaller openings than water at same pressure, numerous small air bubbles will be formed which will increase air-water surface ratio; [2] it takes longer for air bubble to reach surface than for sprayed water droplet to return to water; thus contact time is increased. Low-pressure air can be used to agitate filter sand and will result in reduced backwash time. Compressed air can be stored in receiving tanks which serve as reservoir of power in case of power failures. Air, of course, can be employed to advantage as mixing agent in flocculation processes. Aeration and flocculation may be performed in same treatment unit. Other uses of compressed air include: movement of liquid and solid chemicals; boiler feed control instrumentation, boiler soot blowoff, air-controlled and -operated chlorinators.—*PHEA*

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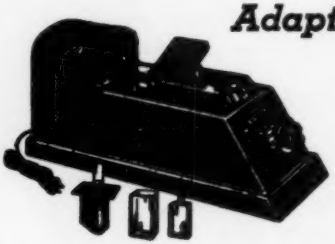

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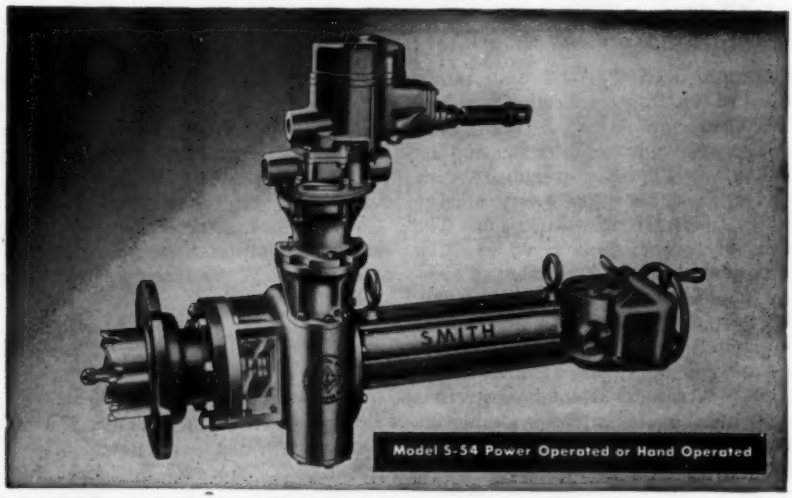

Model S-54 Power Operated or Hand Operated

The NEW Smith S-54 Tapping Machine is the most modern, efficient and economical machine available. The Machine is used with Tapping Sleeves, Hat Flanges, Saddles and Tapping Valves to make 2″ through 12″ connections under pressure to Cast Iron, Cement-Asbestos, Steel and Reinforced Concrete Pressure pipe. Features: 1. Positive automatic feed insures correct drilling and tapping rate. 2. Travel is automatically terminated when tap is completed—cutter and shaft cannot overtravel. 3. Telescopic shaft reduces overall length. 4. Mechanism is housed in heat treated Aluminum Case filled with lubricant. 5. Stuffing Box and Packing Gland is accessible without disassembling machine. Line pressure cannot enter machine case. 6. Extra large diameter telescopic shaft add strength and rigidity. Timken radial—thrust bearings maintain alignment, reduce friction and wear. 7. Worm gearing operates in lubricant, torque is reduced to the minimum. 8. Cutters have replaceable Flat and Semi-V alternate teeth of High Speed Steel or Tungsten Carbide. 9. Flexibility: Hand Operated Machines can be converted to Power Operation by interchanging worm gearing. Bulletin T54 sent on request.

53

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

Section Meetings

Montana Section: The 31st annual meeting of the Montana Section was held in Livingston on Apr. 6–7, 1956. The meeting started with a buffet supper "Get Together" on Thursday evening, Apr. 5. Friday morning the meeting was called to order by Chairman John Morrison. The address of welcome was given by C. J. Wanek, president of the chamber of commerce, for Mayor Anderson of Livingston.

The technical program [which will be listed in full in the December 1956 JOURNAL] covered such topics as microstrainers, the Montana public employees retirement system, main extensions, chlorine feeding, coagulation aids, valve records, consulting-engineer assistance, and public relations.

At the noon luncheon on Friday, the members were brought up to date on Association affairs by National Director Claude Eyer and Vice-President Merryfield. The annual dinner-dance was held Friday evening. Kurt Wiel, city engineer, Miles City, was named to receive the Fuller Award, while Claude Eyer and C. O. Lauer were each presented with a 25-year membership pin.

Officers elected for the coming year are: chairman—Ben Chestnut, water commissioner, Great Falls; vice-chairman—R. G. Cronin, foreman, Water Dept., Montana Power Co., Missoula; trustees—Carl King, city engineer, Chinook, and C. W. Brinck, director, Div. of Environmental Sanitation, State Board of Health, Helena. A. W. Clarkson was reappointed secretary-treasurer.

A. W. CLARKSON
Secretary-Treasurer

Pacific Northwest Section: Perfect weather greeted the Pacific Northwest Section's 29th annual convention in Victoria, B.C., Apr. 26–28, 1956. Mayor Percy Scurrah, of Victoria, gave the address of welcome. The following officers were elected: chairman—Ray Harlock, water superintendent, McNeil Island, Wash.; vice-chairman—Henry Donnelly, water superintendent, Bellingham, Wash.; secretary-treasurer—Fred D. Jones, assistant superintendent, Spokane Water Dept.; director—E. Jerry Allen, assistant superintendent, Seattle Water Dept.; trustee (2 years)—John Geren, water

(*Continued on page 78 P&R*)

Filter Sand and Gravel

Well Washed and Carefully Graded to Any Specification.
Prompt Shipment in Bulk or in Bags of 100 lb. Each

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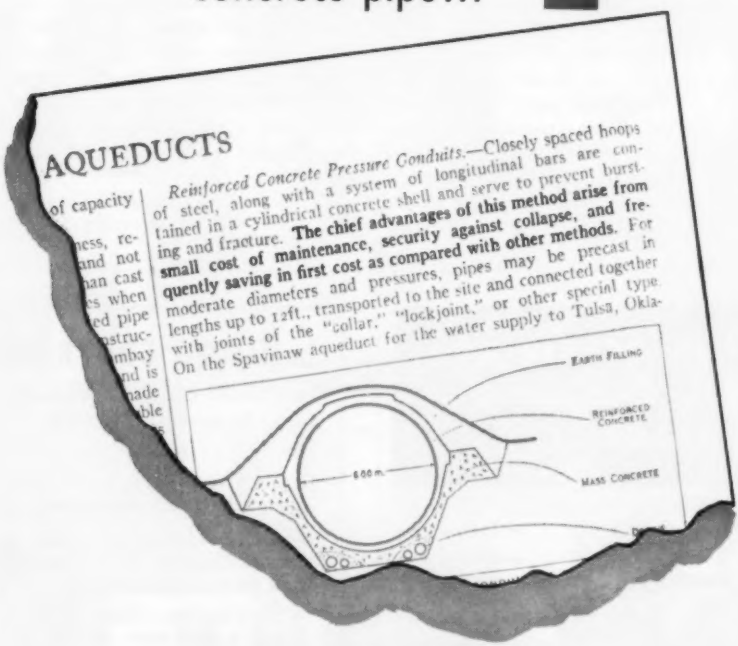
Read what the Unbiased **Encyclopaedia Britannica** says about concrete pipe...



AQUEDUCTS

of capacity ness, re- and not han cast es when ed pipe nstruc- mbay nd is nade ble

Reinforced Concrete Pressure Conduits.—Closely spaced hoops of steel, along with a system of longitudinal bars are contained in a cylindrical concrete shell and serve to prevent bursting and fracture. **The chief advantages of this method arise from small cost of maintenance, security against collapse, and frequently saving in first cost as compared with other methods.** For moderate diameters and pressures, pipes may be precast in lengths up to 12ft., transported to the site and connected together with joints of the "collar," "lockjoint," or other special type. On the Spavinaw aqueduct for the water supply to Tulsa, Okla-

Concrete PRESSURE Pipe

Member companies are equipped to manufacture and furnish concrete pressure pipe in accordance with established national specifications and standards.

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street
Chicago 1, Illinois

WATER FOR GENERATIONS TO COME

Section Meetings

(Continued from page 76 P&R)

superintendent, Salem, Ore. The other trustee, Herb C. Clare, US Public Health Service, holds over for another year.

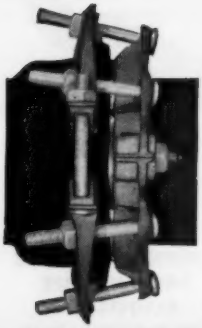
Both total registration and ladies' attendance at the meeting broke all records for the Section. Nearly 450 sat down to the banquet on Friday evening, Apr. 27, in the ballroom, which was filled to overflowing, and some were seated in the parlor and the main dining room. Not only was this the largest convention ever held, but it was unanimously regarded as the most successful.

Carl E. Green, of Carl E. Green & Assocs., Portland, was program chairman and built the program around panel discussions, with audience participation to a marked degree. Friday morning was the only time formal papers were presented. [A list of papers and authors will appear in the December 1956 issue.] The topics discussed included water main cleaning, value of radio equipment, meter repair and records, installation of mains across rivers (film), fish control, highway and water system reconstruction, pipe manufacture (film), covered steel reservoir design and construction, reservoir maintenance and operation, ice worm problems in Alaska, and force account versus contract construction.

At the Friday evening banquet, with Aubrey H. Perry, supervising engineer, Dept. of Health, Vancouver, B.C., as master of ceremonies, the Fuller Award was granted to Alfred H. Labsap, superintendent, Longview, Wash., Water Dept. The Poweil-Lindsay Award was presented to Curtiss M. Everts. C. C. Casad and Chester A. Truman were made Life Members.

FRED D. JONES,
Secretary-Treasurer

FOR REPAIRING BELL AND SPIGOT JOINT LEAKS...



The only clamp with these two important features. Gasket is completely SEALED. Massive ¾" electroplated bolts. 2"—42" incl.

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have served the Water Works Engineer for more than 35 years.

Have you sent for the latest booklet on this helpful LaMotte Service?

For example—did you know that the LaMotte-Pomeroy Sulfide Testing Outfit determines accurately:

- Total Sulfides • Dissolved Sulfides • Hydrogen Sulfide in Sludges and Solutions • Free Hydrogen Sulfide in Air and Gases? •

We will be happy to send full information on this and other LaMotte units used in the Water Works field.

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THE NATION'S No. 1 SOURCE

for dependable pipe line equipment

Like hundreds of Pollard customers, you'll find it mighty pleasant and convenient to order pipe line equipment from Pollard.

Here, under one roof and listed in one comprehensive catalog, are all the time and money saving products you need on the job. Each is guaranteed for dependability, economy. Each is backed by Pollard service.

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MAKE POLLARD YOUR SOURCE FOR PIPE LINE EQUIPMENT. ORDER FROM POLLARD CATALOG 26.

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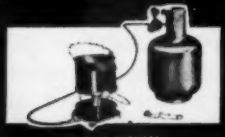

MELTING FURNACE

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If It's from POLLARD . . . It's the Best in Pipe Line Equipment

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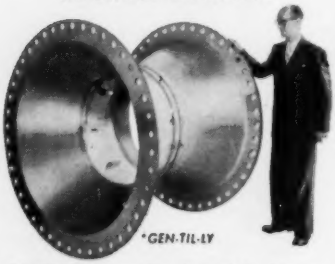
it's REVERSIBLE

The Gentile* FLOW TUBE

measures flow in either direction



*GEN-TIL-LY

REVERSIBLE . . . The Flow Tube is symmetrical, with upstream and downstream ports identical. When the flow is reversed, the differential is reversed. Permits metering reverse flow at lowest possible equipment cost.

LOW INSTALLED COST . . . Average length is only 1½ times the pipe diameter, and straight runs entering and following are not required unless installed near throttling valves or regulators.

ACCURACY . . . Produces differential from points of equal cross-sectional area . . . furnished with head capacity curves, and guaranteed for exceptional accuracy when used with any standard indicating, recording or integrating meter.

LOWEST HEAD LOSS . . . The Flow Tube can be designed to produce a measurable differential with the lowest permanent pressure loss of *any* type head meter.

Write for Bulletin FT-101, or for specific recommendations.

FOSTER ENGINEERING COMPANY

835 LEHIGH AVENUE UNION, N. J.

AUTOMATIC VALVES • CONTROL VALVES
SAFETY VALVES • FLOW TUBES

(*Continued from page 54 P&R*)

The US Senate apparently takes its position as the *upper* house of Congress overseriously. That, certainly, seems to be the only logical explanation why it should consider the public water supply below its standards for drinking in favor of bottled Mountain Valley spring water, when the House —the *lower* house, that is—is both happy and healthy quaffing the Potomac water supplied by the District system. Certainly the senators don't believe in the spring water's curative powers, which even the bottler proved no one took seriously in winning dismissal of a Food & Drug Administration complaint of misleading advertising (as a matter of fact, who knows but what the mineralization may not be responsible for some of the oral diarrhea endemic in their chamber?). And certainly the senators can't be in doubt about the healthfulness of the District's public supply. Which means that the $2,000 per year it cost to bottle-feed them must be charged up to the privilege of their rank.

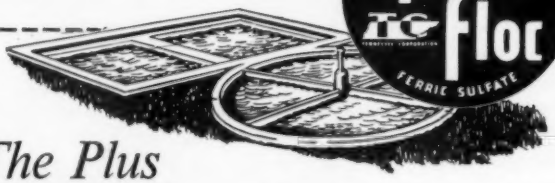
The Hoover Commission has undoubtedly already noted that a saving of $1,990 can be accomplished on this one item, but with us the objection stems more from pride than pocketbook. After all, most of the effort of the water works industry all these years has been devoted to the production of water that is safe and sweet for drinking, not merely for scrubbing the Senate's floors and flushing its toilets. And what kind of sympathy can public water supply expect from a bunch of legislators who think that water comes out of bottles? *We want unicameralism!*

Speaking of taxes, the Navy Bureau of Ships, at least, has taken the citizens' plight to heart, having invented a

(*Continued on page 82 P&R*)

The Superior COAGULANT

Ferri-Floc TC FERRIC SULFATE



With The Plus FACTORS

1. Excellent taste and odor control
2. Increased filter runs
3. Coagulation over wide pH ranges
4. Rapid floc formation
5. Color removal
6. Bacteria removal
7. Manganese and Silical removal
8. Turbidity removal
9. Ease of operation
10. Economy

Ferri-Floc gives smoother, more efficient and trouble free coagulation. Whatever your particular water treatment problem may be, you can depend on Ferri-Floc doing a more than adequate job and doing it efficiently and economically—Ferri-Floc is a free flowing granular salt which can be fed with few modifications through any standard dry feed equipment. It is only mildly hygroscopic, thereby permitting easy and safe handling as well as storage in closed hoppers over long periods of time.

WATER TREATMENT

Efficient coagulation of surface or well waters. Aids taste and odor control—Effective in lime soda-ash softening. Adaptable to treatment of nearly all industrial waters.

SEWAGE TREATMENT

Ferri-Floc coagulates water and wastes over wide pH ranges—it provides efficient operation regardless of rapid variations of raw sewage and is effective conditioning sludge prior to vacuum filtration or drying on sand beds.

LIQUID SULFUR DIOXIDE HIGHEST QUALITY SO_2

Available in: Cylinders, Ton Drums, Tank Cars and Tank Trucks

SULFUR DIOXIDE is effectively used for dechlorination in water treatment and to remove objectionable odors remaining after purification.

COPPER TC SULPHATE

COPPER SULFATE will control about 90% of the microorganisms normally encountered in water treatment more economically than any other chemical.

FREE BOOKLET

Let us send you without charge, a 38 page booklet that deals specifically with all phases of coagulation—just send us a postal card.

TENNESSEE TC CORPORATION

617-29 Grant Building, Atlanta, Georgia

(Continued from page 80 P&R)

detachable container handle designed for use in adapting 10-lb food cans for use as paint buckets. Now if someone could only figure out how to convert the used food can paint buckets into atom bombs, we'd really have accomplished something. But seriously, even though our own experiences with Navy mess suggested that the conversion may previously have been worked in reverse, we're all for economy-mindedness in the Navy as well as in the minor services.

J. J. Chyle, director of welding research, A. O. Smith Corp., Milwaukee, has been elected president of American Welding Society.

John A. Neale has been elected president of the National Fire Protection Assn. Mr. Neale is chief engineer of the National Board of Fire Underwriters, New York.

M. L. Enger, retired dean of the College of Engineering, University of Illinois, died May 12, 1956, at his home in Escondido, Calif. He was 75. In 1907, a year after graduation from the University of Illinois, he entered on a teaching career there. He became head of the Dept. of Theoretical and Applied Mechanics in 1926. From 1934 until he retired in 1949, he was dean of the Engineering College and director of the Engineering Experiment Station.

A Life Member of AWWA (joined in 1915), Dean Enger received the Goodell Prize in 1940. He also belonged to ASCE, serving as director in 1932–34.

(Continued on page 84 P&R)

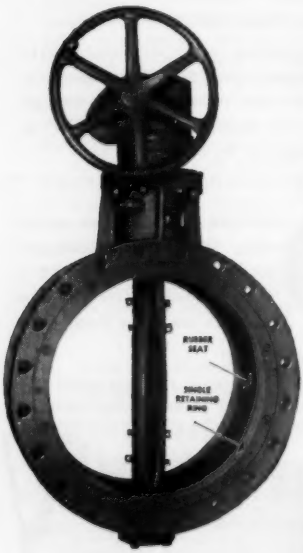
Positive drop-tight shut-off

Easy . . . Efficient . . . Economical with

LEOPOLD

Rubber Seated

BUTTERFLY VALVES



In this design, the seat is of resilient neoprene rubber or pure gum rubber, vulcanized around a steel ring insert, and held in place by a keeper ring. The steel ring, which is "continuous" to eliminate abnormal wearing, increases the firmness of the seat and assures longer service life.

Whether operated manually or by automatic controls, Leopold Butterfly Valves always provide a positive shut-off that's bubble-tight. Made in sizes 6″ to 72″.

Leopold *Write today for descriptive literature!*

F. B. LEOPOLD CO., INC.

COMPLETE WATER PURIFICATION AND FILTER PLANT EQUIPMENT • BUTTERFLY VALVES

DELIVERING WATER CHEAPER

This 48,980-foot water supply line at Spartanburg, S. C., was installed in 50-foot steel pipe lengths. Ease in making up the Dresser joints was the factor in speeding up installation of the line, thereby causing a minimum of inconvenience to property owners.

Pipe Line With Built-in Public Relations

Dresser Couplings build good will with speed, convenience, flexibility, long life

Water pipe installations have a thousand superintendents. They are the public — people whose homes, businesses, or daily routines are affected by the project.

Many watermen have found that use of steel pipe and Dresser Couplings offers an excellent way to build and maintain public good will. This versatile combination helps remove the principal sources of public irritation because of these important results:

Speed. Easy-to-install Dresser Couplings require only two man-minutes per bolt, or less; allow joints to be completed in record time.

Convenience. Most waterworks operators backfill a Dresser-coupled line on the heels of the laying crew. Streets, driveways and sidewalks are tied up for a shorter time.

Flexibility. Dresser Couplings compensate for slight misalignments, permit by-passing obstructions. You can make curves with straight pipe — get up to 4° deflection at each joint of a new main or main extension.

Long life. Leakproof joints eliminate annoyance of redigging for repairs. Specially compounded rubber gaskets protect lines for life.

Good will is just one great advantage of using steel pipe and Dresser Couplings. The job is also done more economically.

Wherever water flows, steel pipes it best. Always put steel pipe and Dresser Couplings in your specifications. Dresser Manufacturing Division, Bradford, Pa. Sales offices in: New York, Philadelphia, Chicago, S. San Francisco, Houston, Denver, Toronto and Calgary.

ONE OF THE DRESSER INDUSTRIES

(Continued from page 82 P&R)

Jasper W. Everett, vice-president and general manager, Springfield (Mo.) City Water Co., died Jun. 2, 1956, at the age of 67. With an engineering degree from the University of Maine (he was born in Norway, Me.), he took the post of superintendent of the South Berwick, Me., water plant in 1912. About 10 years later he became associated with the water works enterprises of the West family, which controls the Springfield company. After several years with various other West-owned utilities, he was transferred to Springfield in 1931 as second vice-president and general manager.

A Life Member of AWWA, which he joined in 1922, Mr. Everett also belonged to the Missouri Water & Sewerage Council, the Missouri Assn. of Public Utilities, and the Missouri Society of Professional Engineers, and was very active in civic affairs.

Harold Leon Fruitman, senior water chemist with the San Francisco Water Dept. at Millbrae, Calif., died May 25, 1956, following a lengthy illness. He was 49. A graduate of the University of California, he had been associated with the department in the above capacity since 1933 except during World War II. A colonel in the US Army reserve, he was decorated for service in Alaska, Canada, and the European theatre.

Mr. Fruitman joined AWWA in 1951. He was also a member of the American Chemical Society and the Society of American Bacteriologists.

125 YEARS
IN CHEMICAL
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SOAP TO SILICATES
Soap, our first product in 1831, was followed 25 years later by silicate of soda used in our soaps. Silicates became our exclusive interest in 1904.
PQ research in silicate properties has uncovered many valuable uses, for example, for raw and waste water treatment. We introduced several new methods of reacting silicates to produce activated silica sols used as coagulant aids.
Results of these studies have been published and are available to you. Let us know how we can help you.
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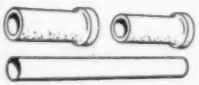
PQ SOLUBLE SILICATES
METSO DETERGENTS

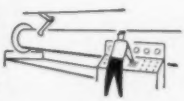
City officials, engineers, contractors will be interested in these . . .

Facts About Steel Water Pipe

COMPARE THE COSTS . . . This scale drawing compares a single 40-ft length of steel pipe with two 16-ft lengths of rigid-walled pipe of the same inside diameter. The steel pipe has thinner walls and a smaller outside diameter; weighs only about one-fifth as much per ft of length. Results: the steel pipe costs less to ship and handle; requires a smaller ditch, fewer bell holes, fewer joints—only 132 per mile.



TESTED FOR STRENGTH . . . *Every* length of steel pipe is hydrostatically tested at the shop in accordance with AWWA specifications—usually to double the working pressure. What's more, steel pipe is designed to withstand from 3 to 4 times the working pressure! It safely resists water-hammer, shock loadings and surge.

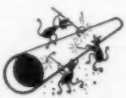


BEAM STRENGTH . . . Steel pipe has the structural strength that is characteristic of tubular steel. It can span long washouts; is often handled in multiple lengths during installation. And steel pipe can stand up under the weight of extremely heavy cover.

RESILIENCE . . . Steel "gives" under stresses that would cause more rigid materials to crack or break. Steel pipe can "absorb" traffic vibration as well as shock due to explosions and earth tremors. Its resilience allows it to transmit much of the strain to the surrounding earth. This is not true of rigid-walled pipe.

LEAKPROOF JOINTS . . . 100 pct bottle-tight joints are a practical reality with steel pipe, whether Dresser couplings or welds are used. Water leakage is prevented; there's no contamination of the contents due to infiltration from without. These joints are quickly made, they're permanent, and they're strong.

CORROSION-RESISTANCE . . . Modern methods of lining steel pipe with hot-spun coal-tar enamel make it immune to corrosion and incrustation. There is no known time limit to this protection. Many tar-enameled lines have been in service for upwards of fifty years. Coal-tar enamel provides the smoothest surface obtainable, assuring high flow coefficients year after year. Coatings and wrappings protect the pipe exterior from moisture, acids and alkalis.



WIDELY USED . . . Large-diameter steel pipe is the growing choice of planners of municipal and industrial water systems. Some recent users of Bethlehem Steel Pipe are: New York City, New Orleans, Philadelphia, Savannah, Reading, Cincinnati, Atlanta, Omaha, Worcester, Colorado Springs and Boston. Further proof of the superior qualities of steel pipe is its use in thousands of miles of large-diameter gas and oil lines, as well as in high-pressure penstocks throughout the world.

If you would like to have further information about steel water pipe, kindly call or write to the Bethlehem sales office nearest you.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

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BETHLEHEM STEEL

BETHLEHEM STEEL

NEW MEMBERS

Applications received June 1–30, 1956

Alcock, H. S., Mgr.-Secy.-Treas., Water & Sewerage Corp. of Greater Corner Brook, Corner Brook, N.F. (Jul. '56)

Arabie, Edward J., Chief Chemist, Valentine Pulp & Paper Co., Lockport, La. (Jul. '56) *PD*

Banks, Jack, Supt., Water Works, Zebulon, Ga. (Jul. '56)

Barrington, John W., Sales Repr., Neptune Meter Co., 4048 W. Taylor, Chicago 24, Ill. (Jul. '56)

Beak, Thomas William, Fishery & Biology Consultant, Box 948, 4 Hamilton St., Hawkesbury, Ont. (Jul. '56) *RP*

Bixler, Donald F., Engr., American Water Works Service Co., 3 Penn Center Plaza, Philadelphia 2, Pa. (Jul. '56) *RD*

Blair, Lawrence R., Sr. Engr., Eng. Div., Dept. of Public Works, City Hall Annex, Hayward, Calif. (Jul. '56) *D*

Blakeney, Roy E., Inspector of Eng. Constr., Water Dept., 215 W. Broadway, Long Beach 2, Calif. (Jul. '56) *MRPD*

Briggs, Howard H., Secy. and Asst. Treas., American Water Works Co., Inc., 908 West St., Wilmington, Del. (Jul. '56)

Burnham, Leon J., Mgr., Nappanee Utilities Co., 205 E. Lincoln St., Nappanee, Ind. (Jul. '56) *MD*

Bustamante, Mario J., San. Engr., Water Works Design, Servicio Cooperative Interamericano de Salud Publica, Talara No. 620, Lima, Peru (Jul. '56) *RPD*

Chamberlain, Thomas S., Tech. Sales, Gen. Chem. Co., 235 Montgomery St., San Francisco 4, Calif. (Jul. '56) *P*

Charles, Wesley L., Supt., Water Dept., Butler, Ohio (Jul. '56) *M*

Chau, Yiu-Kee, Hydrologist, Fisheries Research Unit, Biology Dept., Univ. of Hong Kong, Hong Kong, China (Jul. '56) *RP*

Christman, W. J., Salesman, Johns-Manville Sales Corp., 7912 Bonhomme Ave., Clayton 5, Mo. (Jul. '56) *MRPD*

Cifers, William S., Resident Engr., City Water Co. of Chattanooga, 126 E. 10th St., Chattanooga, Tenn. (Jul. '56) *MD*

Croft, Norman, Munic. Engr., Glen Innes, New South Wales, Australia (Jul. '56) *MRPD*

Cuevas, Robert A., San. Engr., Rader & Assocs., 111 N.E. 2nd Ave., Miami 32, Fla. (Jul. '56) *PD*

Dunn, Earl Harvey, Asst. Dist. Mgr., General Water Works Corp., 815—9th Ave., Altoona, Pa. (Jul. '56) *MPD*

Edwards, Frank William, Mgr., Chicago Office, Stanley Eng. Co., 208 S. LaSalle St., Chicago, Ill. (Jul. '56) *R*

Edwards, Lowell W., Light & Water Com., Wahoo, Neb. (Jul. '56) *MD*

Esmond, James R., Mgr., Enterprise Public Utility Dist., Box 657, Redding, Calif. (Jul. '56) *MRPD*

Evinger, Morris I., Prof. Emeritus, Dept. of Civ. Eng., Stout Hall, Univ. of Nebraska, Lincoln, Neb. (Jul. '56) *MRPD*

Fray, William C., Supervisor of Constr., Bridgeport Hydraulic Co., 835 Main St., Bridgeport, Conn. (Jul. '56) *RPD*

Furanna, A. L., Chief Engr., Public Utilities Com., London, Ont. (Jul. '56)

Gill, John B.; *see* Pilot Manufacturing Co.

Grasso, Salvatore P., Civ. & San. Engr., Anderson-Nichols & Co., Eastman St., Concord, N.H. (Jul. '56) *PD*

Gray, Joseph E., Sr. Draftsman, Helix Irrigation Dist., 4769 Spring St., La Mesa, Calif. (Jul. '56) *D*

Grefe, Erhardt; *see* Truman (Minn.) Light Power & Water Dept.

Hallab, Mahmoud, Dist. San. Engr., Ministry of Public Health, El Tell, Tripoli, Lebanon (Apr. '56)

Henderson, Richard George, Draftsman, Water Dept., Arcadia, Calif. (Jul. '56) *PD*

Hoffman, Raymond, Chief Engr., Associated Dye & Print Co., Inc., 25—6th Ave., Paterson, N.J. (Jul. '56) *MP*

Hopkins, Stephen W., Supt., Water & Sewage, US Naval Housing Projects, Sigbee Park & Peary Court, Key West, Fla. (Jul. '56) *P*

Houska, Howard, Resident Engr., Haskins, Riddle & Sharp, 1009 Baltimore Ave., Kansas City 5, Mo. (Jul. '56) *PD*

Hyde, B. S., Branch Mgr., Atlas Powder Co., Canada, Ltd., 79 Torbarrie Rd., Downsview, Ont. (Jul. '56)

Jorgensen, Alfred W., Engr. & Asst. Gen. Mgr., Crescenta Valley County Water Dist., 2904 Foothill Blvd., La Crescenta, Calif. (Jul. '56) *MD*

Karachi Joint Water Board, Napier Barracks, Karachi, Pakistan (Corp. M. Jan. '56)

King County Water Dist. No. 75, James L. Simon, Supt., 19863—28th Ave. S., Seattle 88, Wash. (Munic. Sv. Sub. Jul. '56)

Lee, Fairman B., Owner, Fairman B. Lee Co., 219 Central Bldg., Seattle 4, Wash. (Jul. '56) *P*

Liggett, William A., Jr. Engr., Rm. 209 City Hall, Portland, Ore. (Jul. '56) *MRD*

Long, John H., Asst. Div. Mgr., American Water Works Service Co., 14½ N. 10th St., Richmond, Ind. (Jul. '56) *M*

Macaulay, J. Frank, Owner, Macaulay Supply Co., 1813 Cherokee Rd., Florence, S.C. (Jul. '56) *D*

MacIndoe, William B., Asst. Secy., American Water Works Service Co., Inc., 3 Penn Center Plaza, Philadelphia 2, Pa. (Jul. '56) *M*

Manahan, G. J., Sales Mgr., The A. P. Smith Mfg. Co., East Orange, N.J. (Jul. '56) *D*

Metzger, Donald Richard, Project Engr., American Water Works Service Co., Inc., 3 Penn Center Plaza, Philadelphia 2, Pa. (Jul. '56)

Middleton, Walter F., San. Engr., Charles W. Cole & Son, 220 W. LaSalle Ave., South Bend, Ind. (Jul. '56) *MRPD*

Miller, Kenneth Gene, Engr., Clyde E. Williams & Assocs., 312 W. Colfax Ave., South Bend, Ind. (Jul. '56) *D*

Morelli, Clifford D., Field Engr., Infilco Inc., Box 151, Fort Lee, N.J. (Jul. '56) *RP*

Morrow, Virgil E., Sales Engr., Johns-Manville Corp., 1220 Madison Ave., Toledo 2, Ohio (Jul. '56) *MRP*

Murphy, John B., Sr. Service Engr., American Water Works Service Co., Inc., 3 Penn Center Plaza, Philadelphia 2, Pa. (Jul. '56)

Navone, Remo, Chief, Branch Public Health Lab., State Dept. of Public Health, Div. of Labs., 1930 Beverly Blvd., Los Angeles 57, Calif. (Jul. '56) *P*

Nichols, Robert M., Civ. Engr., Water Div., Dept. of Public Utilities, Tacoma, Wash. (Jul. '56) *MD*

Pacis, Lauro, Supt. of Branches, National Waterworks & Sewerage Authority, Arroceros St., Manila, P. I. (Jul. '56) *MD*

Page, J. Stuart, Exec. Secy., Munic. Contractors Assn., A.G.C., 815 Thomas Bldg., Dallas 2, Tex. (Jul. '56) *D*

Parker, William F., Jr., Partner, Harold Hoskins & Assocs., 725—9th St., Greeley, Colo. (Jul. '56) *PD*

Patton, James L., Partner, Patton & Kelly, 115 Mary St., Falls Church, Va. (Jul. '56) *PD*

Pilot Manufacturing Co., John B. Gill, Pres., 3970 Pacific Coast Hwy., Torrance, Calif. (Assoc. M. Jul. '56)

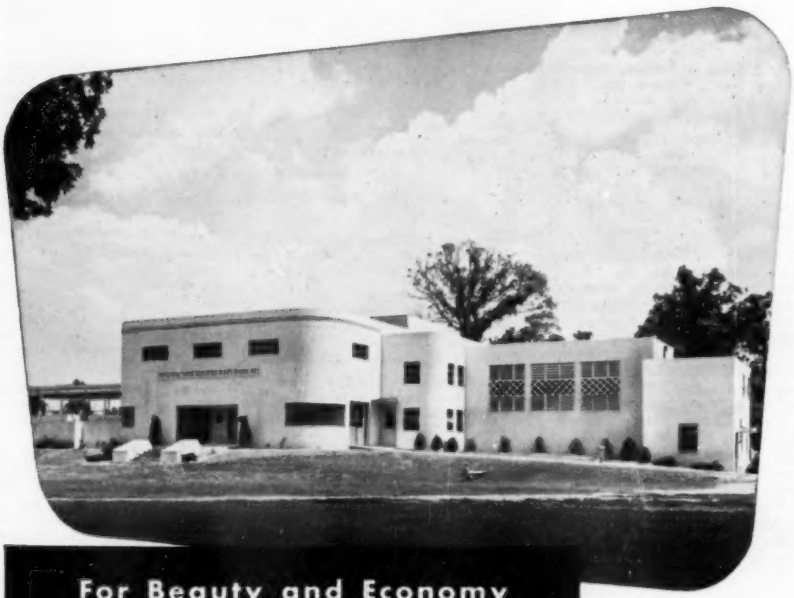
Prince, Fred C., Safety Engr., Utilities Board, 626 S. Gay St., Knoxville, Tenn. (Jul. '56) *D*

Pritchett, Harry R., Corrosion Engr., Rust-Olleum Corp., 7728 E. 6th, Tulsa, Okla. (Jul. '56)

Rathbun, Lowell A., City Engr., Laurel, Mont. (Jul. '56) *MPD*

Reitz, Henry M., Cons. Engr., 101 S. Meramec Ave., St. Louis 5, Mo. (Jul. '56) *MR*

(*Continued on page 88 P&R*)



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Rezvi, Kazim Hussain, Superintending Engr., Karachi Joint Water Board, Napier Barracks, Karachi, Pakistan (Jul. '56) *MRPD*

Roberts, Kenneth L., Hydr. Engr., Federal Power Com., 441 G St., N.W., Washington, D.C. (Jul. '56) *MRPD*

Robertson, James, Robertson & Cave, Inc., 8th Ave. N.W. & River, Great Falls, Mont. (Jul. '56)

Roell, Kenneth A., San. Engr., State Board of Health, State Office Bldg., Madison, Wis. (Jul. '56) *RP*

Schmutz, Jack H., Corp. Secy., Water Works Supply Co., Pompton Plains, N.J. (Jul. '56) *D*

Sharpe, Russell J., Treas., American Water Works Service Co., Inc., 3 Penn Center Plaza, Philadelphia 2, Pa. (Jul. '56) *MRPD*

Shaw, Henry Marchant, Mech. Engr., North Carolina Products Corp., Box 1996, Raleigh, N.C. (Jul. '56)

Shelley, Melvin J., Asst. City Engr., 2811—30th St., Vernon, B.C. (Jr. M. Jul. '56) *MRPD*

Simon, James L.; *see* King County (Wash.) Water Dist. No. 75

Spanos, James A., Mgr., J. M. Rhoades Co., 347 S. Pineapple Ave., Box 669, Sarasota, Fla. (Jul. '56) *RP*

Thompson, A. T.; *see* Thompson Engineering Co.

Thompson Engineering Co., A. T. Thompson Jr., Engr., Box 8292, San Antonio, Tex. (Corp. M. Jul. '56) *MRPD*

Trexler, M. Vincent, Tech. Service Repr., Westvaco Mineral Products Div., 161 E. 42nd St., New York 17, N.Y. (Jul. '56) *P*

Truman Munic. Light Power & Water Dept., Erhardt Grefe, Supt., Truman, Minn. (Munic. Sv. Sub. Jul. '56) *MD*

Waldrop, Guy, Chief Mech. Engr., American Water Works Service Co., 3 Penn Center Plaza, Philadelphia 2, Pa. (Jul. '56)

Wallace, William D., Field Engr., 3617 California Ave., Pittsburgh 12, Pa. (Jul. '56) *MP*

Wedge, William W., Supervisor, Water Dept., Bridgeport Hydraulic Co., 835 Main St., Bridgeport, Conn. (Jul. '56) *D*

Wells, Joseph Van Brunt, Chief, Surface Water Branch, US Geological Survey, Washington 25, D.C. (Jul. '56) *R*

Wetmore, Harold W., Comr. of Public Property, 191 E. 147th St., Harvey, Ill. (Jul. '56) *MPD*

Wheeler, Henry R., Jr., Project Engr., Metcalf & Eddy, 1300 Statler Bldg., Boston 16, Mass. (Jul. '56) *RP*

White, Benjamin E., Safety Engr. Asst., Dept. of Water & Power, 207 S. Broadway, Los Angeles 12, Calif. (Jul. '56)

Woods, Thomas Robert, Tech. Service Repr., Canadian Industries Ltd., Box 10, Montreal, Que. (Jul. '56) *P*

Woolfson S., Jose, Field Engr., Water Supply Dept., Box 286, Quito, Ecuador (Jul. '56) *RPD*

Wright, William M., Chief Operator, Sewage Treatment Plant, 2436 Van Buren St., Hollywood, Fla. (Jul. '56) *M*

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Hayes, J. C.
Heck, R. L.
Ongerth, H. J.
Ordunio, H. M.
Rener, A. C.
Schafer, Frederick
Seevers, W. M.
Weight, W. O.

Canadian
Berry, A. E.
Kline, J. D.
Tassie, G. C.

Chesapeake
Fiedler, A. G.
Levie, A. T.

Florida
Earls, C. E. (2)
Kempter, A. J.
Snow, B. F.

Illinois
O'Connor, C. J.
Stanley, C. M.

Indiana
Garland, J. J.
Shillinger, W. D.
Taylor, L. S.

Kentucky-Tennessee
Bagwell, C. H.
Porzelius, A. F.

Missouri
Harrington, G. P.
Lischer, V. C.
Riddle, W. G.

Montana
Chestnut, B. H.
Clarkson, A. W.

Nebraska
Cramer, J W.
Olsson, J. E.

New England
Marston, F .A.
Silliman, F. B. (2)

New Jersey
Gaffin, Harry
Jones, R. H.
Tygert, C. B.
Zuckert, W. M.

New York
Skaar, R. H.

North Carolina
Mengel, C. W.
Young, E. G.

Ohio
Ames, B. L.
Coleman, E. L.

Pacific Northwest
Anderson, H. K.
Benedetti, A. J.
Braun, P. J.

Pennsylvania
Carns, J. G., Jr.
Jones, E. F.
Murdoch, J. H., Jr. (6)

Rocky Mountain
Dier, C. L.

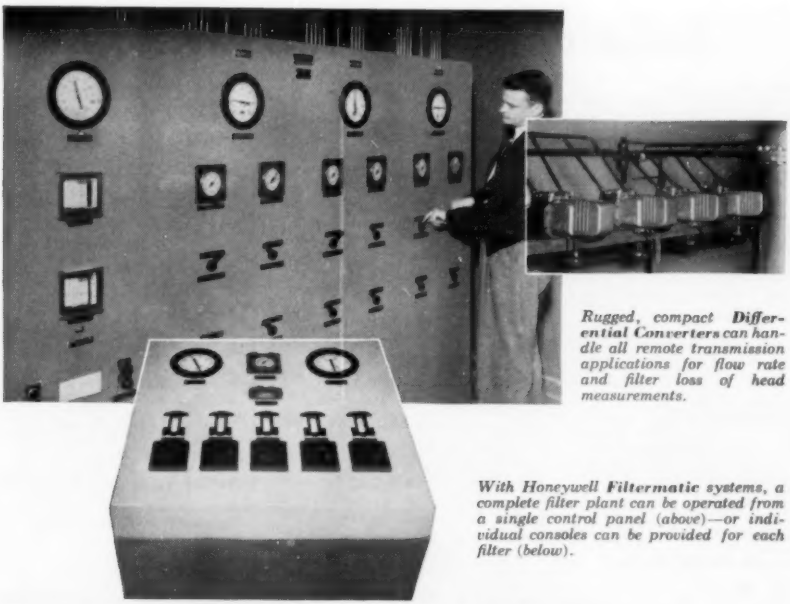
Southeastern
Muckenfuss, C. H.
Simonton, L. R.

Southwest
Frederick, J. T.
Oldt, F. S.
Sanders, R. M.

Virginia
Rettig, G. J.

Wisconsin
Rohlich, G. A.

Foreign
Garcia, L. E.
Ocampo, Lamberto
O'Neill, R. W.
Williamson, A. E.
Zavala, Alfonso



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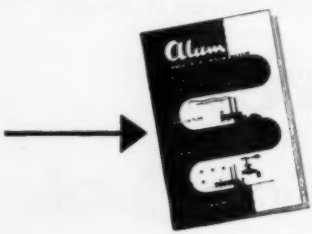

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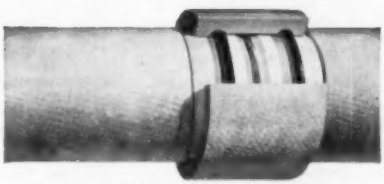

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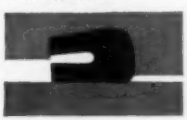

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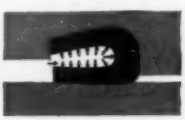

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Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Builders-Providence, Inc. (Div., B-I-F Industries)
Foster Eng. Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
Infilco Inc.
F. B. Leopold Co.

Paints:
Barrett Div.
Inertol Co., Inc.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.

Pipe, Copper:
American Brass Co.

Pipe, Steel:
Alco Products, Inc.
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.

Pipe Cleaning Services:
Ace Pipe Cleaning, Inc.
National Water Main Cleaning Co.

Pipe Cleaning Tools and Equipment:
Flexible Inc.

Pipe Contings and Linings:
Barrett Div.
Cast Iron Pipe Research Assn
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Reilly Tar & Chemical Corp.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
Reed Mfg. Co.
A. P. Smith Mfg. Co.
Spring Load Mfg. Corp.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pipe Vises:
Spring Load Mfg. Corp.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Morse Bros. Mchy. Co.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
Infilco Inc.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Morse Bros. Mchy. Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves; see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
General Filter Co.
Graver Water Conditioning Co.
Permutit Co.

Sodium Aluminate:
Monolith Portland Midwest Co.

Sodium Chloride:
Frontier Chemical Co.

Sodium Hexametaphosphate:
Calgon, Inc.

Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon, Inc.
Cochrane Corp.
General Filter Co.
Infilco Inc.
Morton Salt Co.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

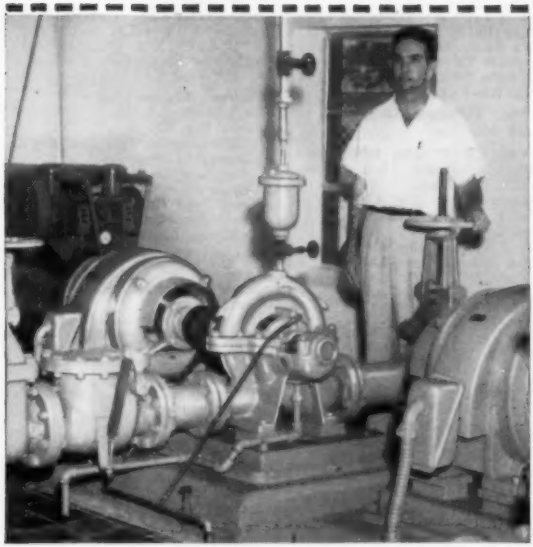
Stops, Curb and Corporation:
Hays Mfg. Co.
Mueller Co.

Storage Tanks; see Tanks

Strainers, Suction:
James B. Clow & Sons
M. Greenberg's Sons
Johnson, Edward E., Inc.
R. D. Wood Co.

Allis-Chalmers

PUMPS Solve a Public Works Problem



Save $30.00 a Month in Power Costs Alone

Here's proof that increased efficiency reduces pumping costs — pays for replacement unit in 2½ years

Duty: 500 gpm at 200-ft head. Power Cost 1.25¢ per kwhr.		
	25-year-old pump	New pump
Rpm	1750	3500
Hp	50	40
Wire-to-water efficiency	53½%	67%
Cost per 1000 gallons	1.46¢	1.18¢
Cost per 12-hr day	$5.26	$4.25
Per month	$158.00	$128.00
A Savings of $30.00 a Month		

● Now, with modern Allis-Chalmers pumping equipment, it is possible for you to replace old outmoded pumps with new equipment — and pay for it out of power savings in an average depreciation period.

For complete information on the Allis-Chalmers pumps for your applications, contact your local Allis-Chalmers representative, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

Allis-Chalmers units are built with that extra measure of strength and ruggedness that will assure long life and low-cost service. Allis-Chalmers pumps and motors also save dollars in maintenance and downtime reduction.

You can get a complete pumping unit from Allis-Chalmers — pump, motor, and control—assembled and ready to run. Allis-Chalmers engineers are at your service to help you in selecting just exactly the equipment to meet your requirements.

A-3037

For MORE PUMP VALUE Get Allis-Chalmers

A-C ALLIS-CHALMERS

ALLIS-CHALMERS

Surface Wash Equipment:
Cochrane Corp.
Permutit Co.

Swimming Pool Sterilization:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Omega Machine Co. (Div., B-I-F Industries)
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Tanks, Steel:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
Builders-Providence, Inc. (Div., B-I-F Industries)
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Tenoning Tools:
Spring Load Mfg. Corp.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.
S. Morgan Smith Co.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Shower Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Shower Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Large Diameter:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Regulating:
DeZurik Shower Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
Henry Pratt Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
Builders-Providence, Inc. (Div., B-I-F Industries)
Infilco Inc.
Simplex Valve & Meter Co.

Waterproofing:
Barrett Div.
Inertol Co., Inc.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Cochrane Corp.
Dorr-Oliver Inc.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

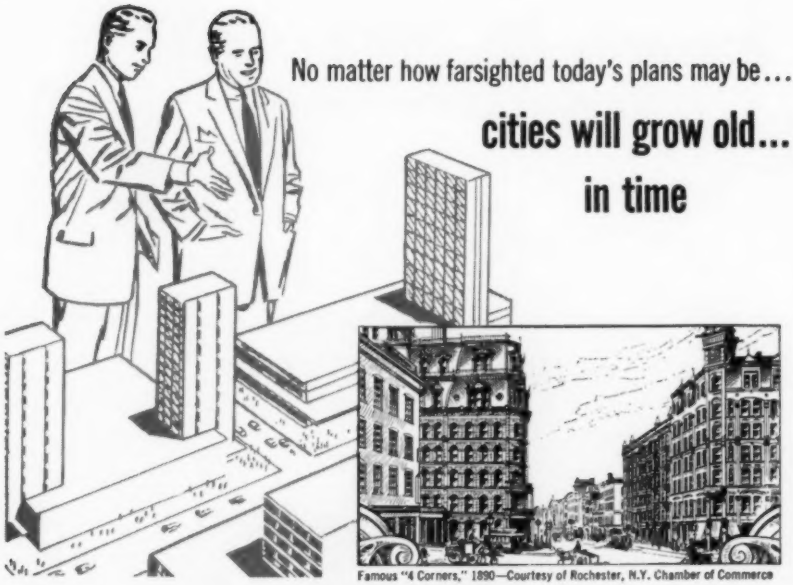
Well Drilling Contractors:
Layne & Bowler, Inc.

Well Screens:
Johnson, Edward E., Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite; see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1955 AWWA Directory.



No matter how farsighted today's plans may be...

cities will grow old... in time

Famous "4 Corners," 1890—Courtesy of Rochester, N.Y. Chamber of Commerce

Your best insurance against obsolescence of your water system... specify EDDY Valves and Hydrants *throughout*

No matter how far into the future your city planning is projected, Eddy's record testifies that Eddy Valves and Hydrants are your best long term investment. Eddy Valve Company's more than 100 years of dependable operation means that, today, you can get replacement parts for any Eddy Valve or Hydrant ever installed. And our ability to continue to do so is your assurance against future obsolescence of your valves and hydrants.

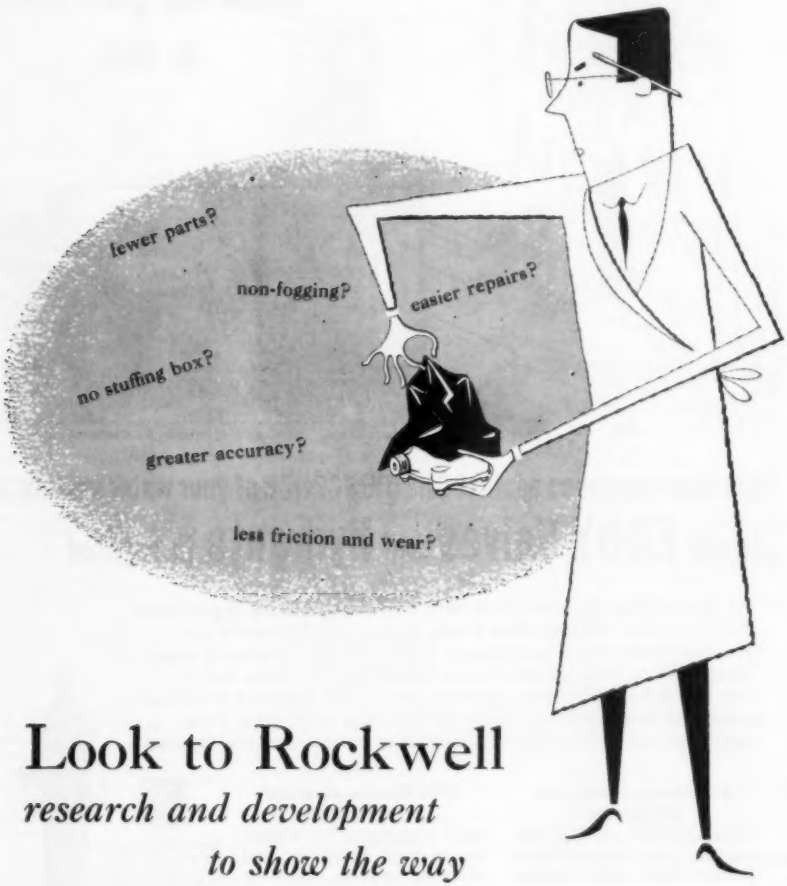
EDDY Bronze-Mounted HYDRANTS open smoothly *with* the pressure and close without water hammer. One man can easily remove all operating mechanism for inspection and repair. Stem held in place below hydrant valve means that there is no water loss due to a bent stem.

EDDY Bronze-Mounted GATE VALVES offer simplicity of design, trouble-free operation and enduring service. Each is truly a finished product of workmanship. These factors, added to personal experience, tell why progressive water works men have relied on Eddy for generations.

Eddy Hydrants and Valves are available with hub, flange or mechanical joint connections to fit any existing or planned installation.

EDDY VALVE COMPANY
A Subsidiary of James B. Clow & Sons
WATERFORD, NEW YORK

What do you want
in the meter of tomorrow?



Look to Rockwell
research and development
to show the way

Rockwell Manufacturing Company
Pittsburgh 8, Pennsylvania

Water Treatment, too, needs INDIVIDUAL DIAGNOSIS

No two water treatment problems are exactly alike. The right solution to each can only be arrived at after a careful study of the local conditions. Variables such as raw water composition, rate of flow and results required automatically rule out the cure-all approach. The installation shown below is a good example of how equipment should be selected to fit the job . . . and not vice versa.

View of the Fort Lauderdale Fiveash Plant. Dorrco Hydro-Treator unit in foreground.
Consulting Engineers: Philpott, Ross & Saarinen, Fort Lauderdale, Florida.

Fort Lauderdale FLORIDA

Uses High-Rate Water Treatment to Meet Needs of Growing Population

Like every progressive city, in 1952 Fort Lauderdale was faced with expansion of water treatment facilities to meet the needs of its rapidly growing population. Careful analysis indicated that high-rate treatment would be the best answer to their problem.

The result was the new 8MGD Fiveash Water Plant which went into operation in December 1953 and has greatly reduced the load on the Old Dixie Plant. Finished water averages less than 50 ppm hardness with zero color. Treatment consists of aeration, softening, filtration and chlorination with a 55 ft. square Dorrco Hydro-Treator mechanism installed for the softening step.

If you'd like more information on the complete line of Dorr-Oliver water treatment equipment, write to Dorr-Oliver Incorporated, Stamford, Connecticut for Bulletin No. 9141.

Every day over 8½ billion gallons of water are treated in Dorr-Oliver equipment

Hydro-Treator T.M. Reg. U. S. Pat. Off.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.

LEADITE

Trade Mark Registered U. S. Pat. Office

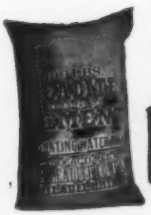
Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%



THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking